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DELAWARE RIVER BASIN COMMISSION

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FINAL PROGRESS REPORT

DELAWARE ESTUARY AND BAY WATER QUALITY SAMPLING AND MATHEMATICAL MODELING PROJECT

GRANT PERIOD: JULY 1, 1967 to JANUARY 31, 1969

OCTOBER 27, 1961

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DELAWARE RIVER BASIN COMMISSION
Trenton, New Jersey

FINAL
PROGRESS REPORT
DELAWARE ESTUARY AND BAY WATER QUALITY SAMPLING AND MATHEMATICAL MODELING PROJECT

10 ref

Water Quality Branch

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Final Report - Delaware Estuary and Bay Water Quality Sampling and Mathematical Modeling Project

I. Introduction

This report for the Demonstration Project for Water Quality Sampling and Mathematical Modeling Project, covers the period from July 1, 1968 to January 31, 1969 and also compiles the information of the first progress report from July 1, 1967 to June 31, 1968.

The Delaware Estuary is defined for purposes of location as the tidal body of water lying between the Delaware Bay and the free-flowing stream of the Delaware River which ends at the Trenton falls. The 85-mile long Estuary runs from River Mile (R.M.) 48.2 to 133.4. River Mile zero begins at the entrance of the Delaware Bay at the point of intersection of the navigation channel extended and a line drawn between Cape May lighthouse in New Jersey and the tip of Cape Henlopen, Delaware.

The data that was obtained by the boat runs represented the effect of the waste discharges coming into the Estuary, stormwater runoff, and the quality of other water from the tributaries of the Delaware River. Since the demonstration grant covered a time period of a year and a half, the water quality data could be related in some fashion to the different seasons of the year, as well as to the various discharges. With the data obtained as a result of the grant and from a parallel continuing water quality sampling program supported by DRBC, approximately two years of data collection has been compiled as of July 1969.

The sampling of the Delaware Estuary was done under contract with the State of Delaware Water and Air Resources Commission which made weekly boat runs over 17 sampling stations located between Fieldsboro, New Jersey near the upper end of the Estuary, and Reedy Island, Delaware just above the lower end of the Estuary. The water analyses from the boat runs have been used in this report to compare the water quality of the Estuary in the study period to that of record from 1949 to 1963. In addition, the water quality data was evaluated relative to the official water quality standards as set forth in the DRBC Regulations.

Specific measurements of parameters such as dissolved oxygen and temperature were used in the refinement of the steady state mathematical model originally developed by the FWPCA Delaware Estuary Comprehensive Study (DECS) staff. Using the model, dissolved oxygen profiles were computed by inserting input loads developed under other sampling programs, including those of waste discharges and tributary streams, by the DRBC in cooperation of its member states. This information was used to currently validate the Estuary model and to provide a basis for future abatement programs and surveillance procedures. Further use of the boat run data was demonstrated by its incorporation into the STORET system for the use by others who need ready access to this information.

II. Objectives

The objectives of this demonstration grant were:

1. To establish a definitive sampling program which would measure water quality on a continuing periodic basis and to establish a surveillance program on the Estuary pertaining to water quality as part of a water quality management program.

2. To develop a base line for Estuary water quality.

3. To update the Estuary mathematical model.

4. To demonstrate the cooperation between governmental agencies to establish and run a sampling program.

This report will evaluate the two years of data in comparison with records of historical data in the Delaware Estuary for the purpose of identifying either trends or differences in particular water quality parameters. The data will also be evaluated with respect to the water quality standards as outlined in the water quality regulations of the Delaware River Basin Commission. This will indicate the quality of the present Estuary water and any potential problem areas that may not have been previously recognized. The parameters that were measured covered a wide area of chemical and physical characteristics.

The important objective of substantiation and improvement of mathematical modeling techniques with the steady-state model will demonstrate that the mathematical model is still valid for dissolved oxygen predictions for current steady-state periods.

III. Procedures

A. Sampling contracts. This demonstration project is being carried out under the direction of the Delaware River Basin Commission with contractual arrangements with the Water and Air Resources Commission of the State of Delaware. The Delaware Estuary was sampled forty-nine (49) times yearly at mid-channel at a depth of 3 ft. below the water surface at high or low water slack at the 17 sampling stations between R.M. 55.0 and R.M. 127.6. The location and description of each station is given in Table 1. A map of the Estuary with the 17 sampling stations is shown in Figure 1. The analyses called for were physical, mineral, nitrogen, oxygen, bacteriological, metal, and other parameters as detailed in Table 2. The stations were sampled at approximately weekly intervals and the samples analyzed in the laboratory except for measurements of temperature, dissolved oxygen and pH, which were made as soon as the sample was collected. The dissolved oxygen was measured by use of the Winkler test as outlined in Standard Methods. The sampling arrangement on the boat consisted of a pump ejecting a continuous stream of water taken from 3 ft. below the water surface.

To complement the boat run program, sampling contracts were entered into with the States of New Jersey, Pennsylvania and Delaware for the collection of monthly samples of the effluent discharges of the major industries and municipalities along the Delaware Estuary and to sample streams tributary to the Estuary and the main stem of the Delaware River at Trenton, for various physical, chemical and biological parameters. The yearly cost to the DRBC for these additional programs is $85,000. Copies of the contracts with the

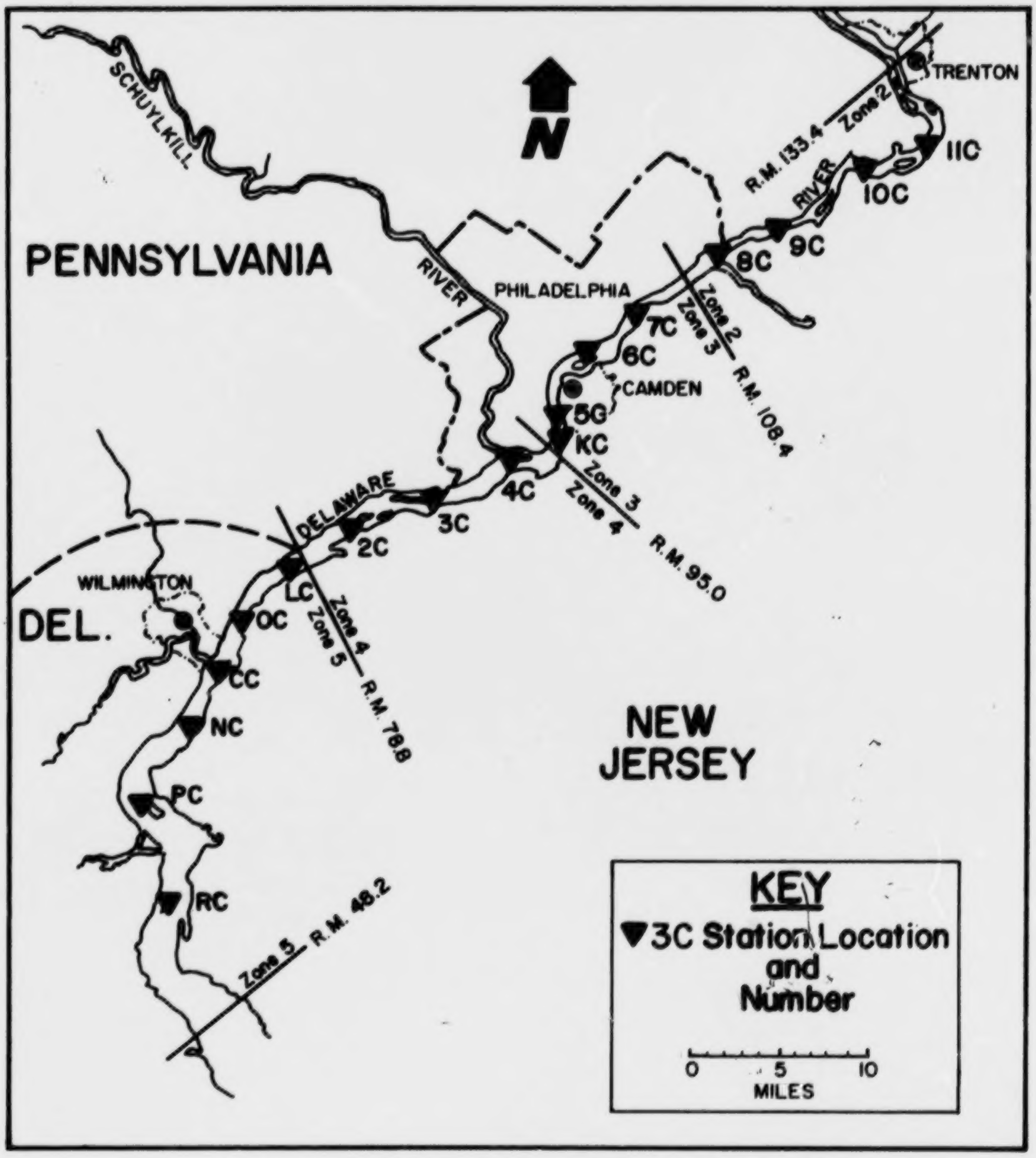


Figure 1 - Station Locations and Water Quality Zones

TABLE 1

	Station Locations		State of Delaware Code
Station Name	River Mileage	Model Section	
Delaware River at Fieldsboro, N. J.	127.48	2	11C
Delaware River at Florence, N. J.	122.49	3	10C
Delaware River at Burlington-Bristol Bridge, Bristol, Pa.	117.80	4/5	9C
Delaware River at Torresdale, Phila., Pa.	110.70	7	8C
Delaware River at Palmyra, N. J.	107.08	8	7C
Delaware River at Philadelphia Northeast Sewage Treatment Plant, Phila., Pa.	103.96	9	6C
Delaware River at Ben Franklin Bridge, Phila., Pa.	100.15	12	5C
Delaware River at Wharton Street, Philadelphia, Pa.	98.51	13	KC
Delaware River at Navy Yard, Phila., Pa.	93.18	15	4C
Delaware River at Paulsboro, N. J.	87.90	16	3C
Delaware River at Eddystone, Pa.	83.98	17	2C
Delaware River at Marcus Hook, Pa.	78.07	19	LC
Delaware River at Oldmans Point, N. J.	74.88	20	0C
Delaware River at Cherry Island, Del.	70.96	21	CC
Delaware River at New Castle, Del.	65.96	23	NC
Delaware River at Pea Patch Island, Del.	60.55	27	PC
Delaware River at Reedy Island, Del.	54.94	29	RC

TABLE 2.

LIST OF ANALYSES

Physical analyses
1. Temperature--water and air
2. Turbidity
3. Conductivity
4. ORP
5. Threshold odor (above Frankford Creek only)

Mineral Analyses
1. pH
2. Acidity
3. Alkalinity
4. Hardness
5. Chlorides
6. Total phosphates

Nitrogen analyses
1. Kjeldahl
2. Ammonia
3. Nitrite
4. Nitrate

Oxygen analyses
1. Dissolved oxygen
2. 5-day biochemical oxygen demand at 20°C
3. Chlorophyll-A

Bacteriological analyses (membrane filter method)
1. Total coliform
2. Fecal coliform
3. Fecal streptococci

Metals analyses
1. Chromium
2. Copper
3. Iron
4. Nickel
5. Zinc

Miscellaneous analyses
1. Warburg studies--8 stations once every month, FWPCA to conduct analyses
2. Solids balance
3. Phenols- analysis on bi-monthly basis
4. Syndets (Measured as MBAS, above Frankford Creek only), analysis on bi-monthly basis

respective member states of the Commission for sampling analyses are included in Appendix A. These contracts exemplify the cooperative relationship of the member states with the Delaware River Basin Commission. The collection and analysis is carried on by the respective State laboratories and field personnel. Flexibility exists in that additional special samples may be taken when the need occurs.

Analysis of the samples provided information to be used in the mathematical model for reverification purposes for 1967 and 1968 steady-state periods. Measurements of effluents of the major discharges provided information to estimate the amount of ultimate carbonaceous oxygen demand that was entering the Estuary. Using this information, current loadings to the Estuary could be put into the mathematical model, thus enabling the results to be compared to the observed dissolved oxygen profiles.

B. Steady-state mathematical model. The mathematical model being used in conjunction with this demonstration grant was developed by the Delaware Estuary Comprehensive Study (1) staff to project dissolved oxygen profiles for various levels of waste treatment. The effluent quality requirements of the Commission's Standards were based on model predictions. The effects of organic waste discharges, stormwater overflow, benthic deposits, and tributary organic loadings were used in the model along with observed flows that were occurring during a steady state period. This model of the Delaware River Estuary relates the physical, chemical, and biological characteristics to parameters of water quality. The DECS model (1) contained thirty (30) sections which were established in lengths of 10,000 or 20,000 ft. Section 1 begins at the Calhoun Street Bridge in Trenton (R.M. 133.4). The end of Section 30 is located at Artificial Island (R.M. 50.0). Figure 2 shows the location of these sections in the Estuary.

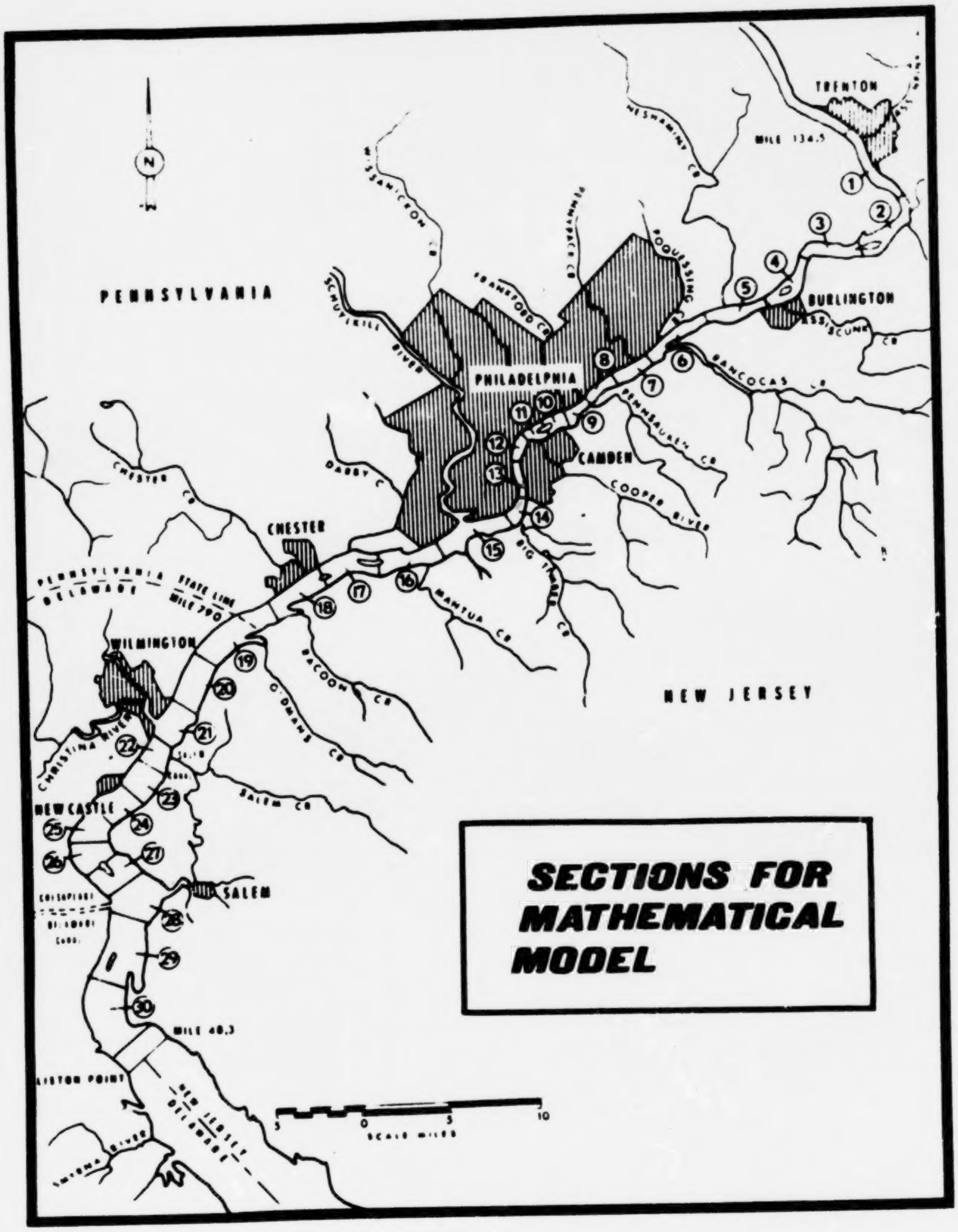

SECTIONS FOR MATHEMATICAL MODEL
N
TRENTON
MILE 134.5
NESHAMINY CR
PENNSYLVANIA
SCHUYLKILL RIVER
WISSAHICKON
PENNYPACK CR
FRANKFORD CR
POQUESSING CR
BURLINGTON
ASSISCUNK CR
RANCOCAS CR
PHILADELPHIA
PENNSAUKEN CR
CAMDEN
COOPER RIVER
DARBY C
CHESTER CR
CHESTER
BIG TIMBER CR
MANTUA CR
PENNSYLVANIA STATE LINE
DELAWARE
MILE 79.0
WILMINGTON
RACCOON CR
OLDMANS CR
CHRISTINA RIVER
NEW JERSEY
SALEM CR
NEW CASTLE
SALEM
CHESAPEAKE DELAWARE CANAL
MILE 48.3
LISTON POINT
NEW JERSEY
DELAWARE
SMYRNA RIVER
5
0
5
10
SCALE MILES
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30

Figure 2

The model is a two-system model which has steady state transfer functions to convert the effluent BOD to stream BOD and the stream BOD to stream D.O. By combining the two systems, the dissolved oxygen stream value is related to the amount of organic load being discharged. The turbulent diffusion was accounted for in a mathematical model by O'Connor (2), which incorporated the Streeter-Phelps formula. In 1963, a computational procedure was established by Thomann (3), which included the terms for turbulent diffusion of the O'Connor estuary model. Instead of having a continuous function of distance along the longitudinal axis, Thomann used an incremental method in which average conditions in each segment were determined. The model may also be used for predictions of conservative substances such as chlorides. While most of the work that has been done was for dissolved oxygen predictions, runs have been made, for verification purposes, with the time-varying model for predictions of salinity and dissolved oxygen.

Once the mathematical model was programmed, the model was used with coefficients that have been either calculated or established by field studies. If the observed distribution of dissolved oxygen can be reproduced from the known input loads, the verification procedure is successful and then the model can be used for prediction purposes with other anticipated loading conditons.

As noted previously, the steady-state model has been used mainly to determine the dissolved oxygen profile of the Estuary. The discharge loads are in terms of ultimate oxygen demand (UOD), both first stage (FSUOD) and second stage (SSUOD). The mass balance equation was written for each segment, taking into account the advection, diffusion, the deoxygenation and reaeration and the sources or sinks of oxygen to represent the benthal demand and the net effect of photosynthesis and respiration.

The physical characteristics of the Estuary were determined by the DECS (1) using USGS charts and field measurements. First stage decay coefficients were established by running BOD tests of the river water at various stations; reaeration coefficients were calculated by O'Connor's equation. Diffusion coefficients were estimated and the flow basis was determined as the average flow over a defined steady state period at Trenton. Surface runoff was calculated by an area method when tributary flows were not gaged. According to the DECS, (1) the net daily photosynthetic oxygen contribution was zero. One oxygen source that was added to the input data was that of supersaturated water entering the Estuary at the fall line at Trenton.

During the DECS study, parts of the Estuary were mapped for benthal deposits and benthal uptake rates were established in the laboratory. These were then used, proportional by area, to determine the benthal loads which were inserted as an input to the model as a continuous demand. The dissolved oxygen saturation values were included as a data set so the final dissolved oxygen profile could be calculated.

Because the organic loading is composed of both carbonaceous and nitrogenous demand, the model as set up, calculates one set of data at a time. Therefore, the model was run with the carbonaceous loads first to determine their dissolved oxygen deficit and then run to obtain the deficit by the nitrogenous loads. The sum of these two deficits added to the saturated dissolved oxygen values in the water produced a dissolved oxygen profile that would be expected under the conditions of flow, temperature and particular loadings used.

The DECS study initially sampled 44 of the 90 industries and municipalities to determine the net discharges which represented at least 90% of the total waste volume entering the Estuary. The discharged carbonaceous demand has increased due to the growth of industries then existing on the Estuary and to the establishment of other industries.

State sampling contracts to collect and analyze effluent samples were initiated in July 1967. The analyses included BOD's, discharge flows, and other physical, chemical and biological parameters. On the basis of approximately two years of data, average BOD values were calculated for the majority of industries and municipalities and combined with the sampled flow information to give discharge loads. For the purpose of this study, estimates of the FSUOD were calculated, using the factor of 1.4 as the La/BOD5 ratio. Where samples had not been taken, the most recent DECS figures were used. These discharges were added to the section inputs of stormwater runoff and tributary loads. Since no information was gathered on nitrogenous loadings, these were not readjusted from those used by DECS. The computer program was run on an IBM 360/75 at the

University of Pennsylvania where a contract had been established to rent computer time.

C. Time-varying model. The theoretical basis for the time-varying model is essentially that of the steady-state model, except that the programming was changed to allow for an expansion of another variable--namely, time. Greater flexibility existed in this model in the options available for estimating certain coefficients. The time-varying model allows periodic inputs of information--at daily or weekly intervals--to be used in order to predict periodic dissolved oxygen profiles or to give profiles at any one station over the course of a year. Essentially, the time-varying model is a series of steady-state models whose equations are solved for each time interval. This model was developed by DECS up to the point of verification for dissolved oxygen predictions. It had been used successfully to predict salinity profiles at the critical flows of the 1964 drought. Current data on chlorides and flows were used with this model in order to show its effectiveness for the current study. The chloride or salinity level in the Estuary depends on the amount of flow in the river and the concentration of chlorides at the end of the Estuary, or in this case, at the last section of the model.

D. STORET Procedures. Procedures were set up to insert all of the Delaware boat run data into the STORET system. As is the usual procedure for STORET, code numbers were assigned for the locations of the seventeen stations and the various parameters that were to be included. At the writing of this report, most of the boat run information received as a result of this demonstration grant has been inserted into STORET.

IV. Results

A. Compilation of Data, July 1967 to June 1969. Analyses carried out were divided into six general groups--physical, mineral, metal, nitrogen, oxygen, and bacteriological sampling. The data are presented both in tables and in graphs, depending on which would be the most expedient method of showing differences and trends.

From the compilation of data of temperatures in the Estuary, the averaging of one station to illustrate the change over the year sufficed since the temperature variation at the stations during a sampling run was very small. Comparisons of the temperatures from more than one station will be done later in this report to determine whether any changes have occurred in the past twenty years. The station chosen to represent the temperature in the Estuary was that of Marcus Hook. Figure 3 shows the average monthly temperature variation over the study period. An average temperature range from 41° in the winter to 79° in the summer was experienced.

Other parameters that were measured are better illustrated in Table 3 in which averages of these at five stations, Burlington Bristol Bridge, Ben Franklin Bridge, Paulsboro, Marcus Hook, and Reedy Island are calculated over the study period. The physical analyses include total solids, suspended solids, and turbidity, while measurements of minerals include acidity and alkalinity. For the metals, the minimum, mean, and maximum values of iron are given. For zinc, only the maximum values are shown, and for copper, chromium, and nickel, all values were below 0.1 mg/l. According to these yearly averages, the change in concentration along the Estuary of the acidity, alkalinity, chlorophyll-A, and turbidity is very small.

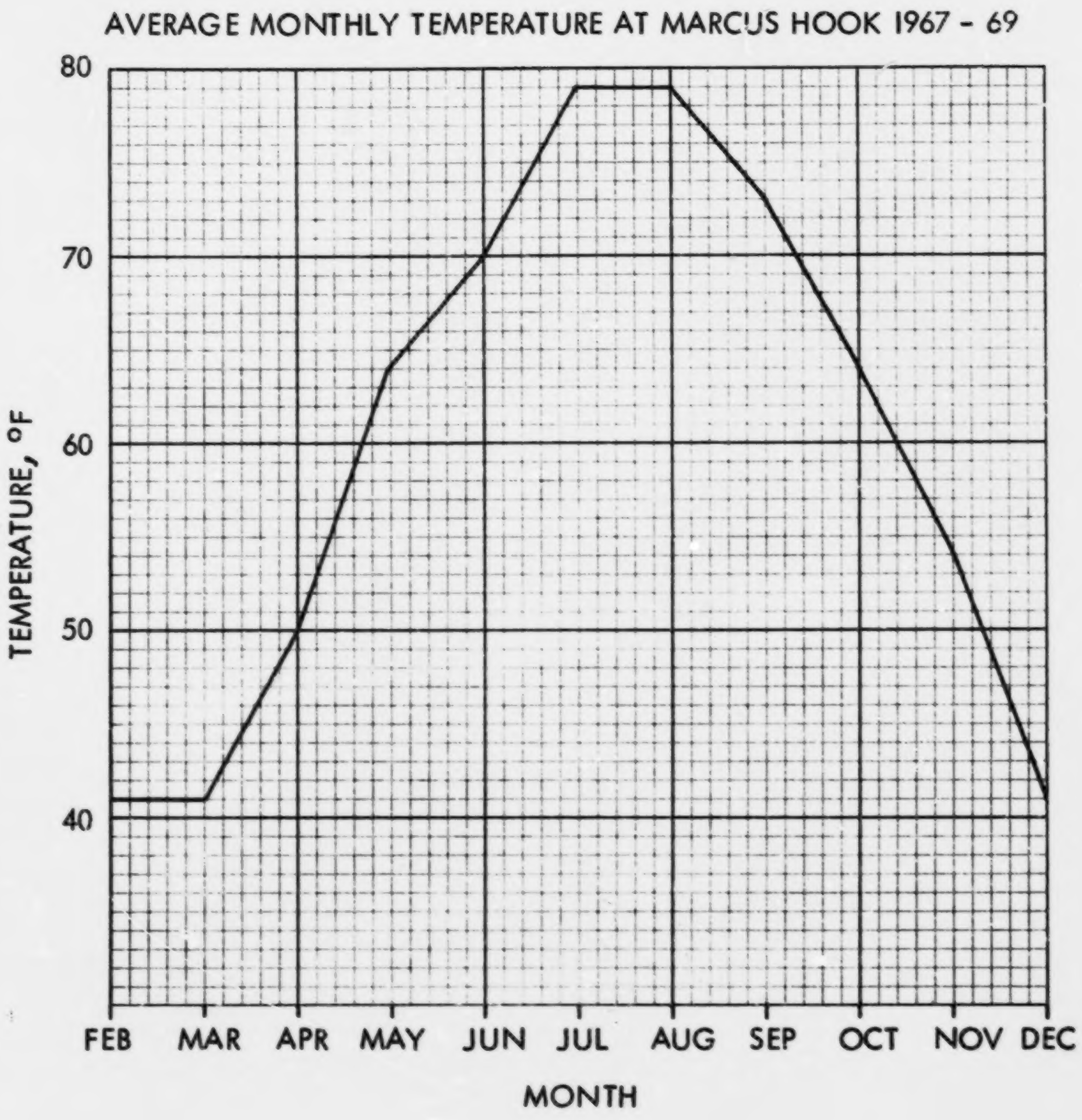

AVERAGE MONTHLY TEMPERATURE AT MARCUS HOOK 1967 - 69
80
70
60
50
40
TEMPERATURE, °F
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 3

TABLE 3

1967–69 Values

	Acidity mg/l			Alkalinity mg/l			Chlor. A mg/m^3			Tot. Solids mg/l			Sus. Solids mg/l			Turbidity units			Iron mg/l			Zinc* mg/l	Cr	Cu	Ni
	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Max.			
Burl. Bristol Bridge	2	4	6	26	34	44	6	20	58	100	140	170	4	22	52	9	15	29	.35	.71	1.99	.12	All values less than 0.1 mg/l		
Ben Franklin Bridge	4	6	8	25	34	44	6	23	60	130	180	430	2	26	100	9	13	17	.39	.83	1.94	<.10	"		"
Paulsboro	5	7	10	26	33	43	4	35	97	150	190	270	-	-	-	9	15	22	.59	1.01	2.23	.12	"		"
Marcus Hook	6	9	13	23	28	37	5	34	75	150	290	710	10	17	26	10	27	26	.85	1.33	2.40	.14	"		"
Reedy Island	4	8	15	11	26	31	7	34	89	1090	3270	5470	6	52	20	17	27	45	.73	1.50	3.20	.14	"		"

*Minimum and Mean values all less than 0.1 mg/l

Chlorophyll-A which is a measure of the amount of phytoplankton and plant life, sometimes called primary productivity, averages 29 mg per cubic meter. Its concentration is slightly higher at the lower end of the Estuary compared to the upper end. Looking at both the total solids and the suspended solids measurements (Table 3), it is seen that they are relatively constant along the Estuary except at Reedy Island. The sharp increase here is primarily due to the increase of dissolved solids caused by the high salt concentration of bay water. Analyses for iron shows a steady increase both in the average and in the minimum and maximum values beginning at the upper end of the Estuary. Zinc generally measured less than 0.10 mg/1, which is the level of sensitivity for the test. Likewise, chromium, copper, and nickel throughout the study period measure less than test sensitivity.

Figure 4 showing the average monthly specific conductance for the 1967-69 period and also the mean flow at Trenton, represents the variations of the specific conductance with the season of the year and the location in the Estuary. The average specific conductance is highest in the low flow periods of the year, occurring at approximately 1100 micromhos. Over the yearly period, the specific conductance is highest at the station farthest downstream. This is due to the high concentration of salt as the salt water of the bay predominates the lower end of the Estuary. Specific conductance can also be correlated to the chloride concentration and was the usual method of chloride measurement. The specific conductance is progressively lower the further each station is up from the Bay. The values at the Ben Franklin and Burlington Bristol Bridges were essentially the same, except in the summer and fall season.

AVERAGE MONTHLY SPECIFIC CONDUCTANCE AND FLOW (AT TRENTON) 1967 - 69

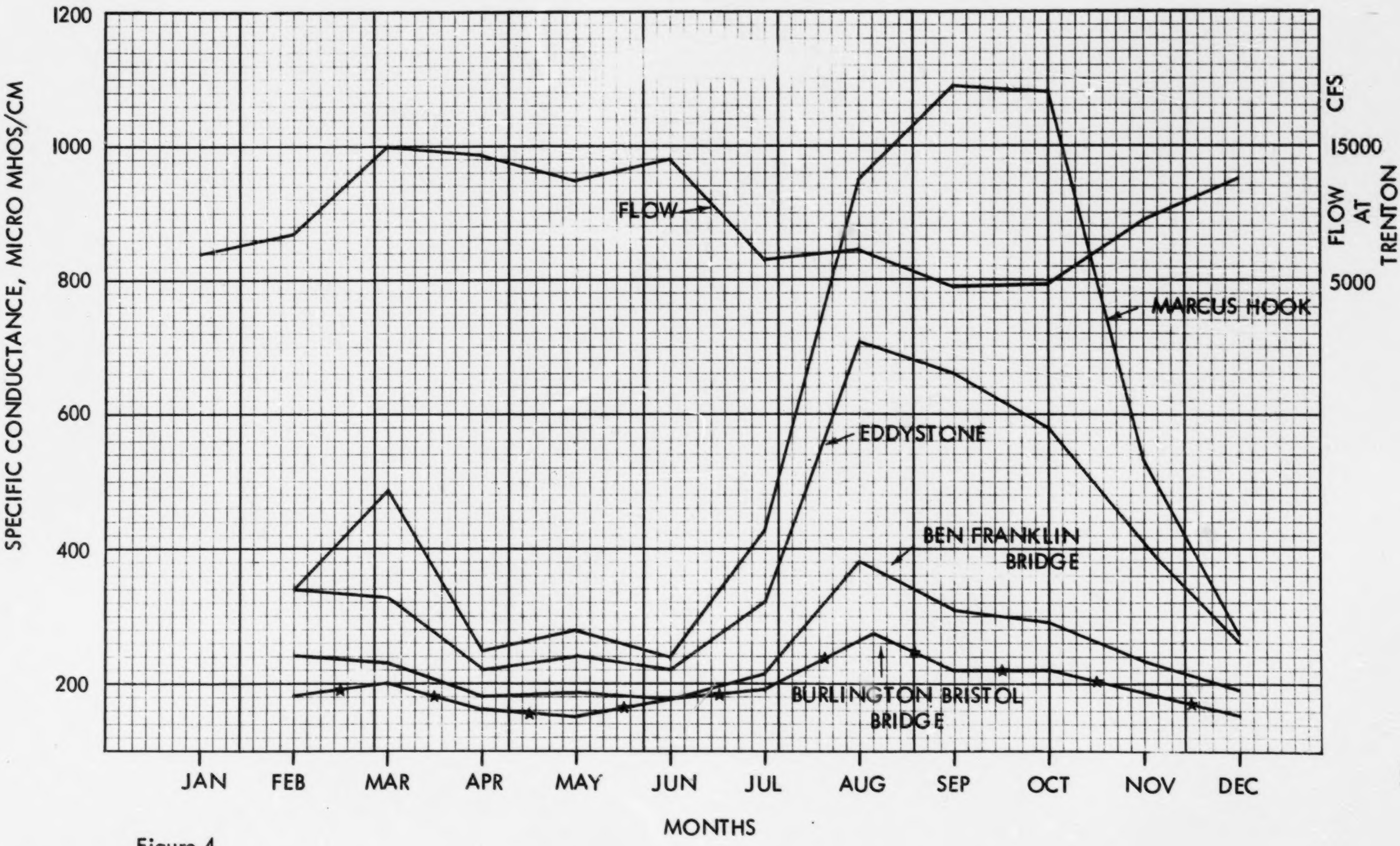


Figure 4

Temperature, dissolved oxygen, pH, chlorides, and specific conductivity, as well as suspended and total solids, were tabulated by monthly average over the study period. These are presented in Table 4 and are represented at four stations--Burlington Bristol Bridge, Ben Franklin Bridge, Eddystone and Marcus Hook. Although the temperature and dissolved oxygen profiles are more easily seen by graphical representations, the monthly averages over the study period are included in the table for compilation purposes. As would be expected, the higher temperatures occur during the summer period along with lower dissolved oxygen values. In general, the temperature along the length of the Estuary is very uniform at any one time. The dissolved oxygen values, generally, were higher in the winter months than in the summer months due to the higher saturation potential of cold water and to the reduced biological activity. The critical period of dissolved oxygen values occurred during the summer months and this period was analyzed in greater detail in a later section of this report where a mathematical model of the Estuary is used to compute predicted values based on the flow, temperature, and loads discharged into the Estuary.

According to the median monthly pH values, the Estuary water is slightly alkaline above the Burlington Bristol Bridge, but below it the pH decreases slightly to the acidic side. Although there are periodic lower values of pH in parts of the Estuary, the monthly values do not reflect these extremes. Again, comparison of total and suspended solids shows that most of the solids are in the dissolved state. At the upper stations, the total solids are fairly uniform throughout the year, except during the late summer when the low flows permit the lower Estuary water with a higher salinity concentration to push up the Estuary and increase the amount of dissolved solids. This is most evident at Marcus Hook. The other group parameters, nitrogen, oxygen, and bacteriological analyses, will be discussed in the next section.

B. Data Evaluation.

1. Comparison of Data Analyses of 1949-63 and 1967-69.

In order to relate the data of the boat runs to historical values, comparisons were made with a summary of data on various stations of the Delaware River from Bristol to Marcus Hook, Pennsylvania (4). The period covered was from August 1949 to December 1963 at eight stations, four of which were used in this report; the Burlington Bristol Bridge, the Benjamin Franklin Bridge, Eddystone, and Marcus Hook. The historical data represent monthly sampling at each of the stations. The sampling trips were scheduled without regard to tidal, climatic, or other environmental conditions. Comparative data from the boat runs on temperature, dissolved oxygen, pH, chlorides, and specific conductivity was presented in Table 4.

The pH did not change greatly with season, therefore, the pH is graphically presented as a function of distance in Figure 5 showing the median pH of the 1967-69 and 1949-63 periods at the Burlington Bristol Bridge, Benjamin Franklin Bridge and Marcus Hook stations. In general, the 1967-69 median pH are somewhat above those of the period of 1949-63. The largest difference occurs at Marcus Hook where the median pH for the later period is 6.8 as compared to 6.5.

TABLE 4.

Month	T°C	D.O. mg/l	pH	Cl mg/l	Specific Conductance Micromhos	Tot. Susp. Solids mg/l	Total Solids mg/l	T°C	DO	pH	Cl	Cond.	Tot Sus. Solids	Total Solids
			Marcus Hook								Eddystone			
Feb	5	5.5	6.6	28	340	-	-	5	7.0	6.8	25	340	20	198
M	5	6.0	6.8	84	515	35	259	5	6.8	6.9	35	331	35	217
A	10	4.5	6.7	18	248	33	170	10	4.5	6.8	15	228	35	158
M	18	2.6	6.8	24	280	26	203	18	2.4	6.8	17	243	24	179
J	21	2.5	6.7	20	237	20	151	21	2.7	6.9	18	219	26	160
J	26	2.2	6.9	39	433	8	180	26	1.5	7.0	22	326	17	221
A	26	1.8	6.8	72	950	15	278	26	1.7	7.1	29	710	24	236
S	23	1.9	6.7	120	1092	28	505	23	1.9	6.9	66	664	23	252
O	18	1.8	6.6	230	1085	39	714	18	1.5	6.8	76	589	28	327
N	12	3.2	6.9	56	530	17	229	12	3.2	6.9	28	394	25	241
D	5	7.0	6.7	20	272	37	172	5	7.8	6.7	20	264	37	218
			Benjamin Franklin Bridge								Burlington Br. Bridge			
F	5	9.4	7.0	20	240	18	153	3	12.3	7.2	16	180	12	116
M	4	9.0	7.1	19	231	38	184	4	10.8	7.3	17	201	36	154
A	10	6.5	7.0	10	179	30	133	11	9.2	7.3	<10	161	23	104
M	18	4.2	7.0	13	185	23	144	18	7.7	7.3	<10	152	21	125
J	22	4.2	7.0	14	175	38	139	22	6.3	7.3	12	174	32	163
J	26	2.0	7.1	17	216	26	150	26	5.3	7.3	14	189	15	136
A	26	1.9	7.1	20	379	17	188	26	5.0	7.4	15	276	17	162
S	23	1.8	7.0	23	306	24	187	22	5.1	7.3	16	219	26	174
O	19	1.6	6.9	23	289	19	428	18	5.9	7.2	16	220	19	152
N	10	6.0	7.0	14	234	26	153	9	10.0	7.2	11	190	13	165
D	4	9.8	6.8	15	191	26	143	4	12.4	7.0	12	159	20	113

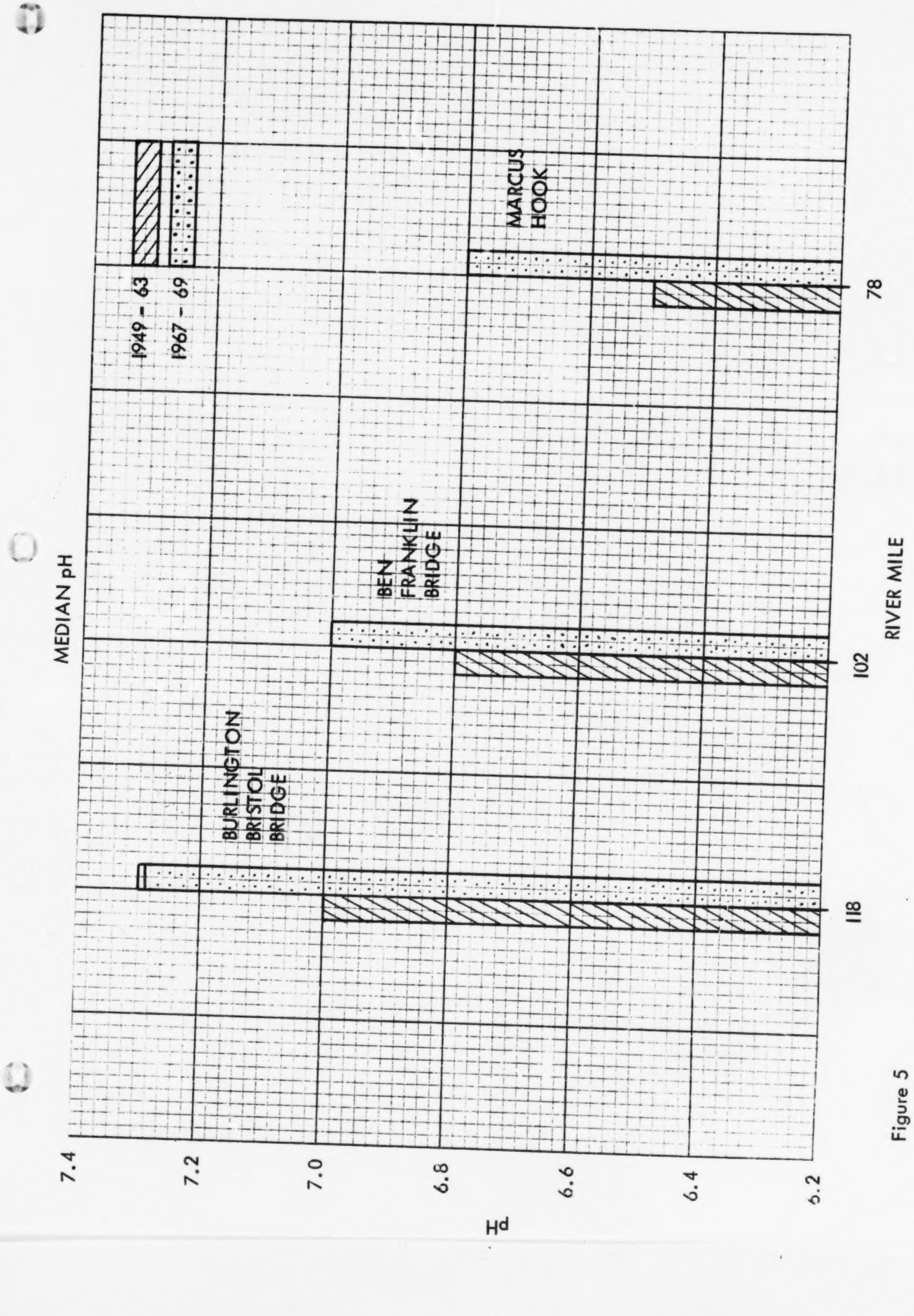

MEDIAN pH
pH
7.4
7.2
7.0
6.8
6.6
6.4
6.2
1949 - 63
1967 - 69
BURLINGTON BRISTOL BRIDGE
BEN FRANKLIN BRIDGE
MARCUS HOOK
118
102
78
RIVER MILE

Figure 5

Specific conductance values of the two study periods could not be fully evaluated without an indication of the corresponding average flows. Figure 6 shows the mean monthly flows at Trenton for each of the periods. In the months from July to October, both average flows were very similar and ranged range between 5,000 and 7,000 cfs. The spring flows of the two study periods were quite different with the 1949-63 April flow 10,000 cfs higher than the 1967-69 flow. However, in Figure 7, the effect that these flow differences had on the April specific conductance along the entire Estuary was minimal since it rose slowly in both cases from between 100 to 150 micromhos at Burlington to 200 to 250 micromhos. For the month of October in both study periods, the value was slightly higher at around 200 micromhos. During periods of low flow, such as October, the specific conductance greatly increased at R.M. 80 to between 1100 and 1800 micromhos. Although the average October flows in both study periods were similar, the specific conductances at the lower end of the Estuary are quite different. The month of April and October were picked for this comparison because, in general, April had the largest and October the lowest discharge for the 1967-1969 study period. According to the October specific conductance, based on tables of the relationship between specific conductance and chlorides, the 250 mg/l chloride level for the 1967-1969 period was approximately at Marcus Hook. This 250 mg/l level would correlate with approximately 1115 micromhos of conductance.

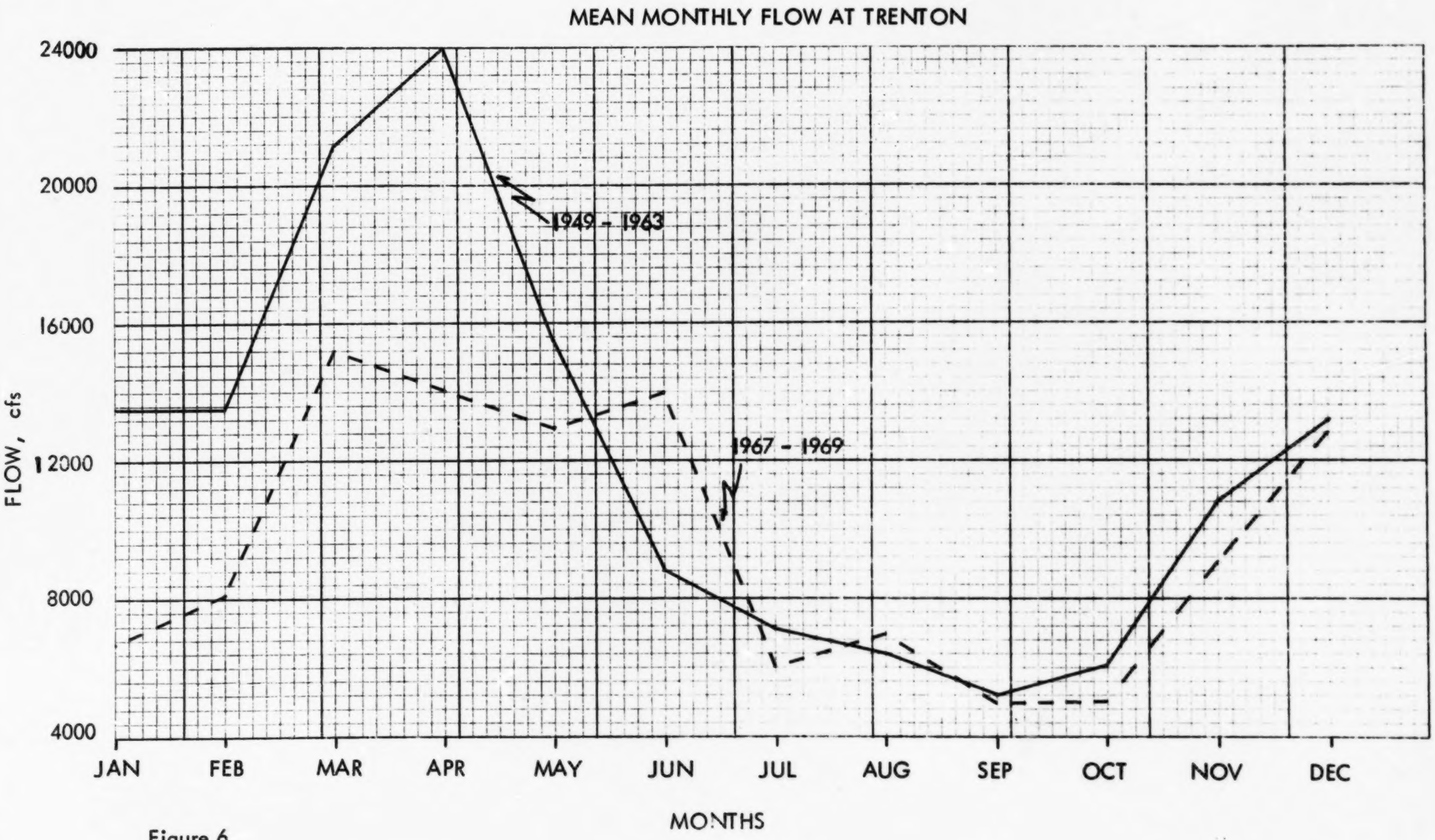

MEAN MONTHLY FLOW AT TRENTON
FLOW, cfs
24000
20000
16000
12000
8000
4000
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTHS
1949 - 1963
1967 - 1969

Figure 6

SPECIFIC CONDUCTANCE

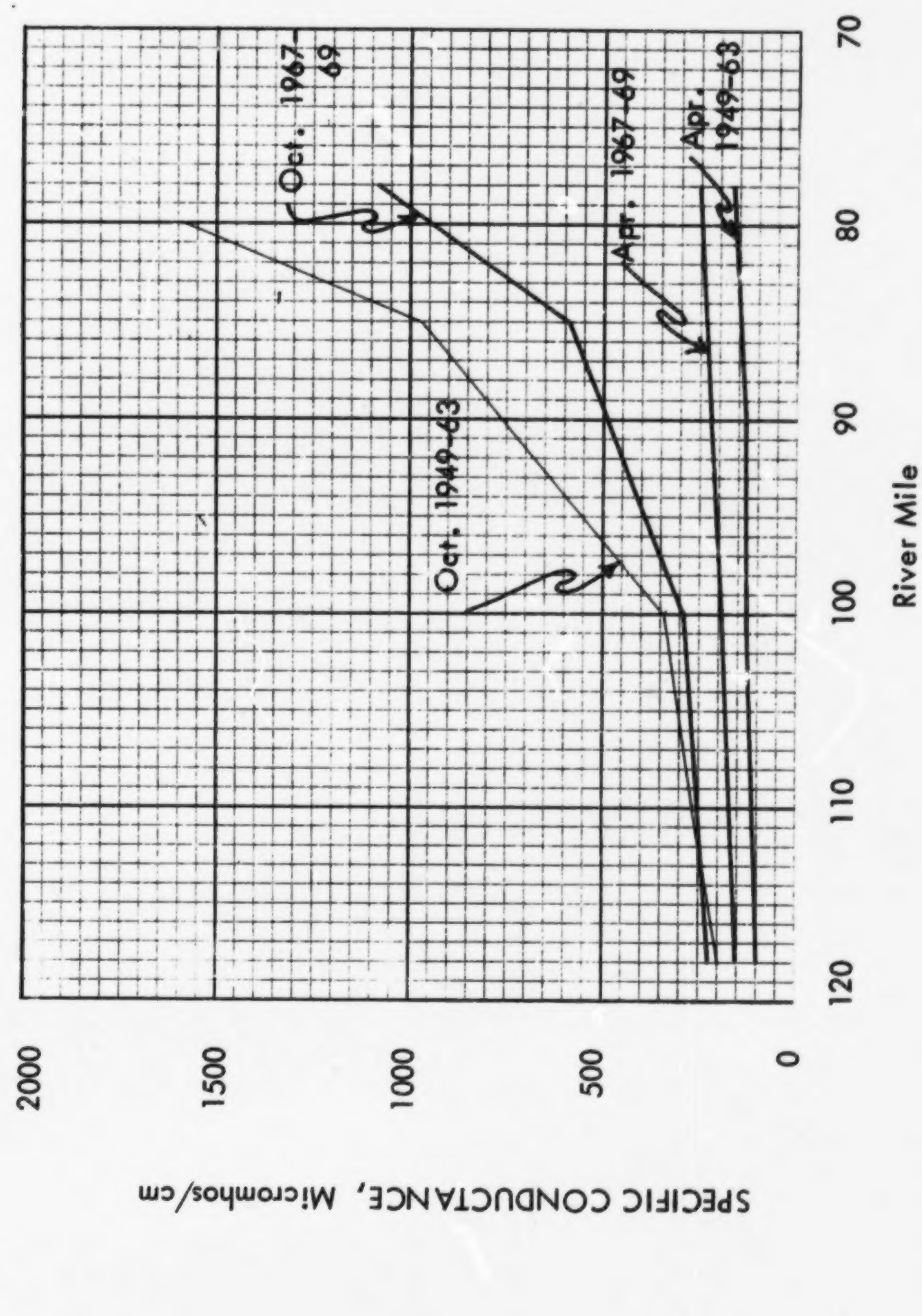
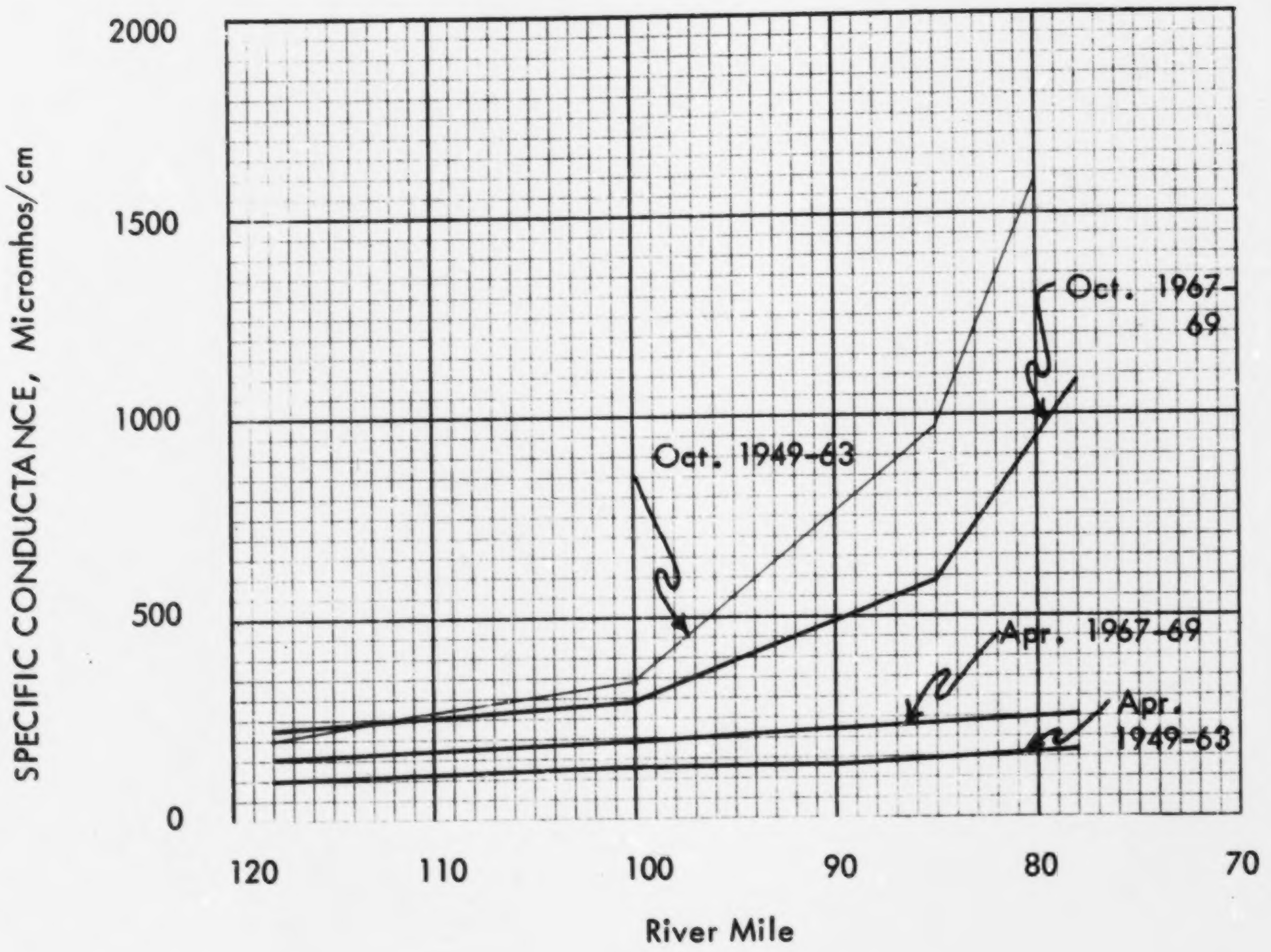


Figure 7

Comparisons of temperature in the Estuary at the Benjamin Franklin Bridge and Marcus Hook stations are shown in Figures 8 and 9. As is expected, the lower temperatures occur in the winter months and the higher in the late summer periods of low flow. The maximum average temperature, in both study periods in July and August, was at approximately 80° F at both stations.

Analysis for chlorides was also made in both studies. However, since chlorides are closely related to salinities and, therefore, to the measurement of specific conductance, comparison of chloride concentrations are not included for the 1967-1969 study. Chlorides averaged between 20-40 mg/l, but were higher in the lower part of the Estuary in the late summer and early fall. This was similarly true to the 1949-1963 period.

Suspended solids were measured in the 1967-1969 period and the average monthly concentration at the Benjamin Franklin Bridge shown in Figure 10. The 1949-1963 data included a measurement of suspended sediment which may not be comparable to the suspended solids determinations of 1967-1969. Therefore, no comparison is made. According to the average monthly values of suspended solids, there is a large variability, but no real trend is demonstrated. The suspended solids at Ben Franklin Bridge range from 20 to 40 mg/l. This range is valid for the other stations throughout the Estuary.



SPECIFIC CONDUCTANCE

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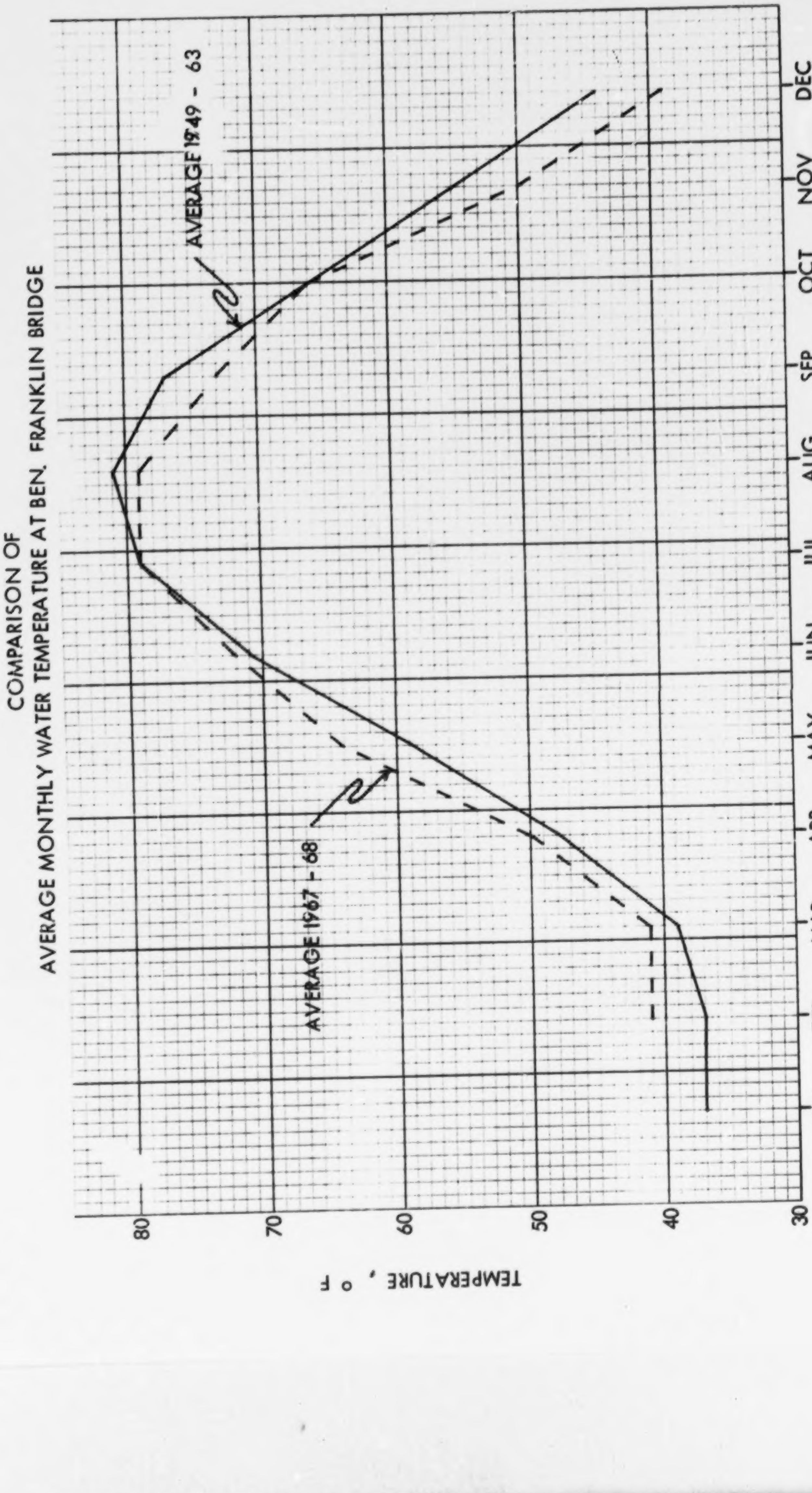


COMPARISON OF
AVERAGE MONTHLY WATER TEMPERATURE AT BEN. FRANKLIN BRIDGE

Figure 8

COMPARISON OF
AVERAGE MONTHLY WATER TEMPERATURE AT MARCUS HOOK

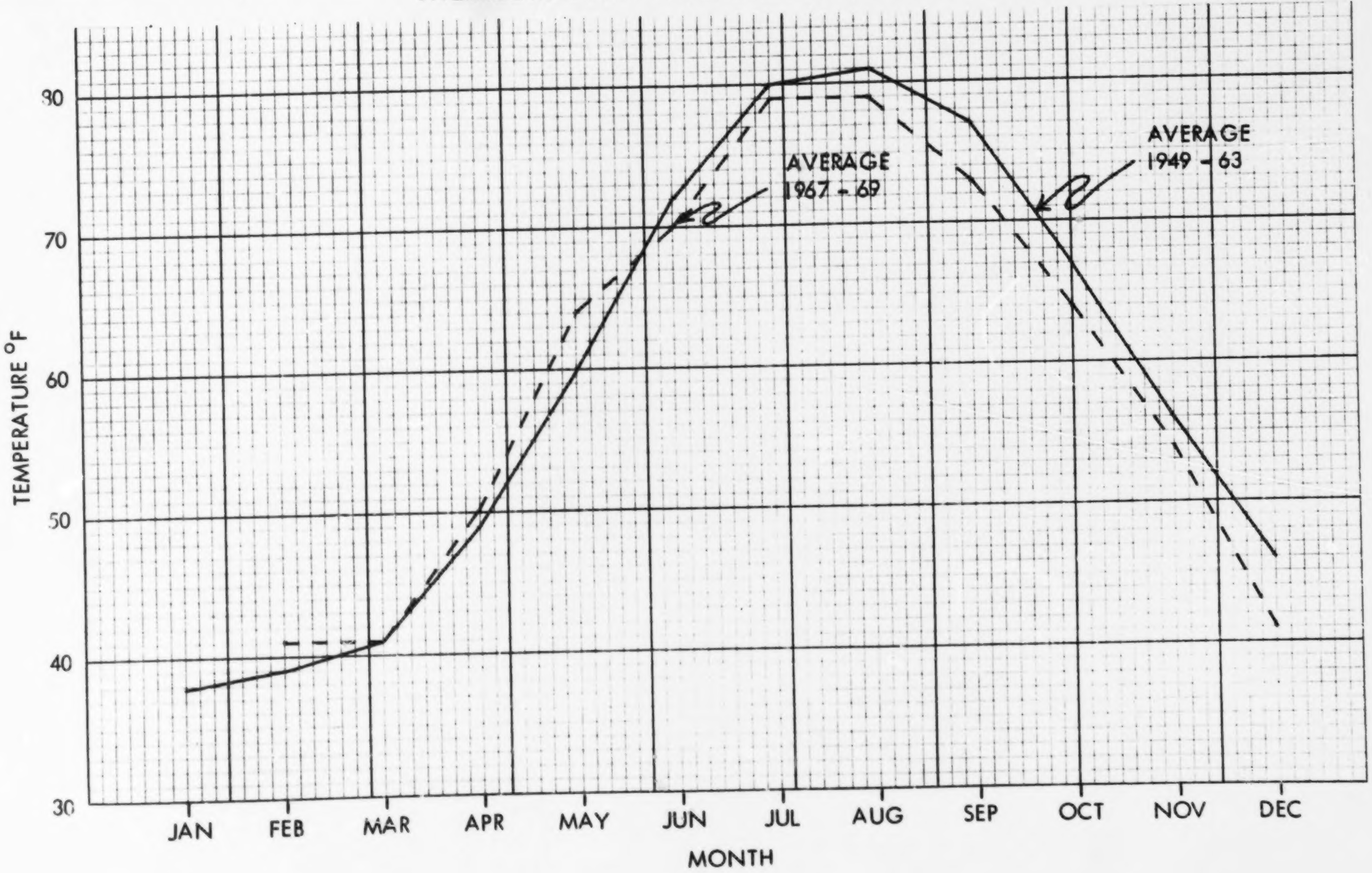
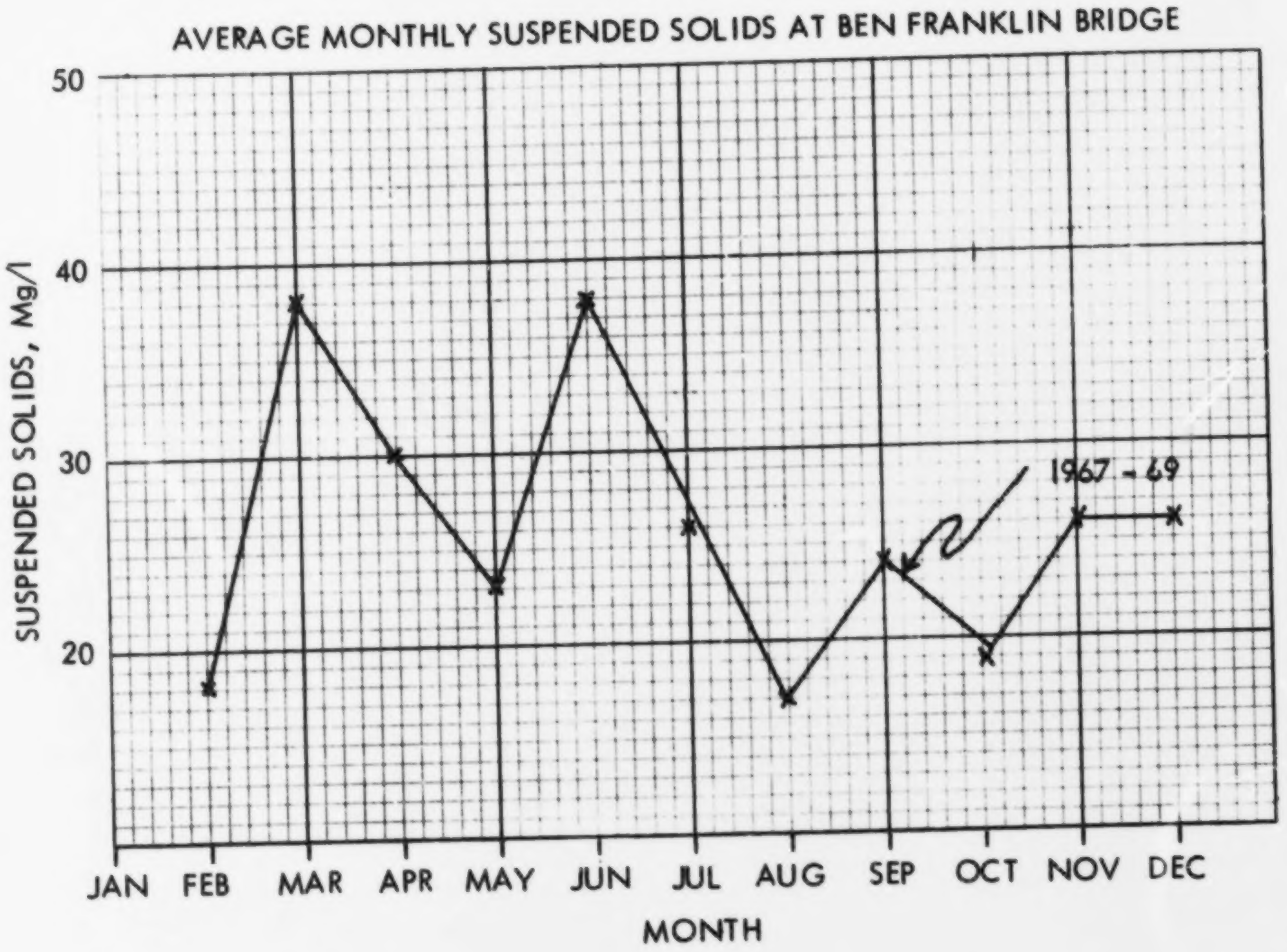


Figure 9



AVERAGE MONTHLY SUSPENDED SOLIDS AT BEN FRANKLIN BRIDGE

Figure 10

The representations of the 1968 steady-state dissolved oxygen profile and the July to September average of 1949 to 1963 are shown in Figure 11. Quantitative comparison cannot be made since the flows and temperatures were different for each of the periods and because the 1949-1963 profile was based on stations covering a shorter length of the Estuary than that of the boat run stations. According to the DECS, the standard deviation of the dissolved oxygen measurements in 1964 in the Estuary was 1 mg/l. At one standard deviation, assuming the data are normally distributed, the two curves can be loosely interpreted to not differ significantly through most of the Estuary. A difference between profiles does seem to exist between Sections 1 and 9 since 1949-1963 profile exhibited a much higher shoulder than the 1968 plot, a difference of almost 2 mg/l in Section 9.

2. Comparison of Stream Sampling Data to Stream Standards. The Basin Regulations - Water Quality (5) of the Delaware River Basin Commission give stream standards for tidal interstate streams. Stream quality objectives were established in each of four Estuary zones for dissolved oxygen, pH, total alkalinity, temperature, phenols, odor, synthetic detergents, turbidity, radioactivity, chlorides, and hardness. The dissolved oxygen requirements in the Estuary differ from zone to zone as shown in Figure 11. Based on daily average concentrations, the Zone 2 dissolved oxygen objective is 5 mg/l; in Zone 3 and Zone 4 and part of Zone 5 - 3.5 mg/l; and from R. M. 70 to R. M. 59.5 is 4.5 mg/l and the remainder of Zone 5 is 6 mg/l. Higher values are required during fish passage seasons in the spring and in the fall.

COMPARISON OF DISSOLVED OXYGEN PROFILES

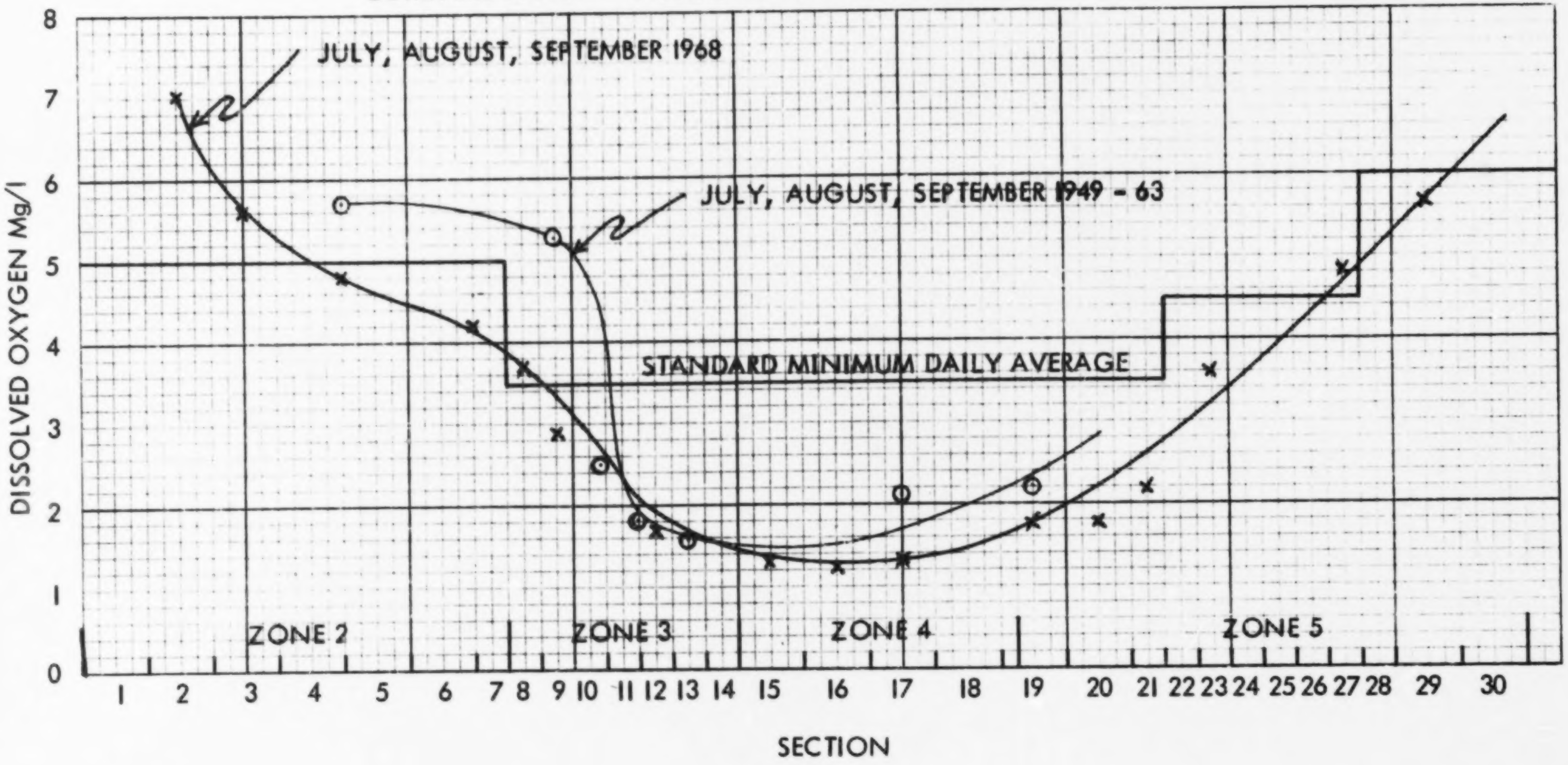


Figure II

a. Dissolved Oxygen. Referring to Figure 12, which shows a steady state dissolved oxygen profile for July 11 to September 10, 1968, the seasonal average in Zone 2, Section 1 to 7, ranged from 4 mg/l to 7 mg/l. On the basis of the DECS work, the daily average concentration is statistically one-half mg/l less than the seasonal average. In Zones 3 and 4, which corresponds to Section 8 to 20, the seasonal average dissolved oxygen level was below 3 mg/l and for most of these two zones was below 2 mg/l. In Zone 5 the dissolved oxygen requirements step up twice--first to 4.5 and then to 6.0 mg/l. The seasonal curve for 1968 was for the most part below these steps.

summer

? ,

During the spring and fall fish runs in which anadromous fish pass up and down the Estuary, a level of 6.5 mg/l of dissolved oxygen has been set between April 1 and June 15, and from September 16 to December 31. This requirement is based on a seasonal average. Figures 13 and 14 show the minimum, average and maximum values during the two fish run seasons at four stations in the Estuary for 1968 and 1969. In Figure 13 where the spring seasonal average dissolved oxygen is given, the average dissolved oxygen level was 8.2 mg/l at the Burlington Bristol Bridge. The dissolved oxygen reached a low value at about 3.5 mg/l at Marcus Hook and then increased to 6.2 at Reedy Island. For the September to December fish passage season the average dissolved oxygen at both Burlington Bristol Bridge and Reedy Island is higher than 6.5 mg/l. As is evident in both Figures 13 and 14, each station has very large ranges between minimum and maximum values with the minimum fall season dissolved oxygen at the Ben Franklin Bridge going to 0.2 mg/l. It is not possible to evaluate qualitatively what the

spring
fall

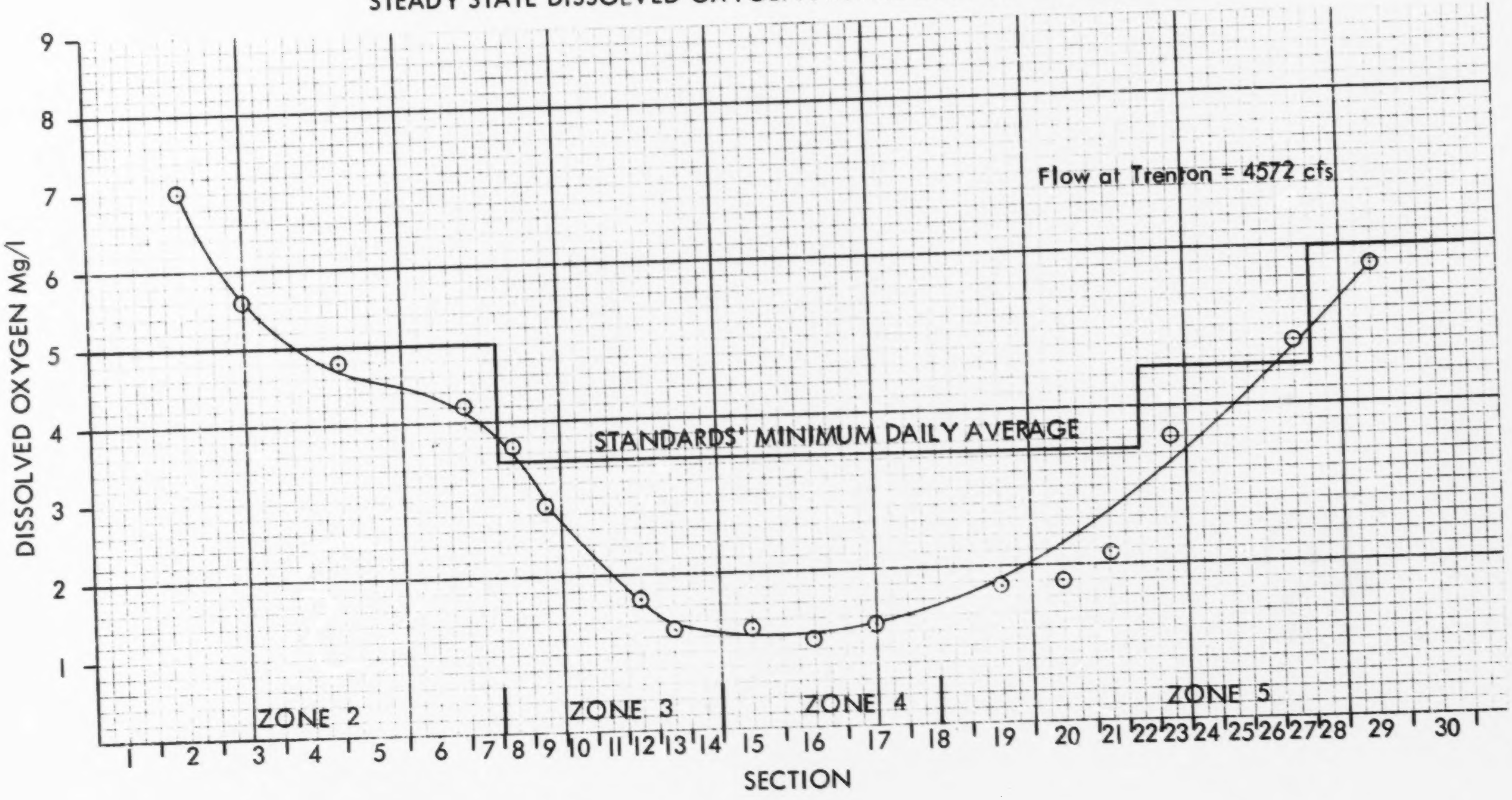

STEADY STATE DISSOLVED OXYGEN PROFILE JULY TO SEPTEMBER 1968

Figure 12

DISSOLVED OXYGEN - FISH PASSAGE PERIOD

April 1 - June 15, 1968-69

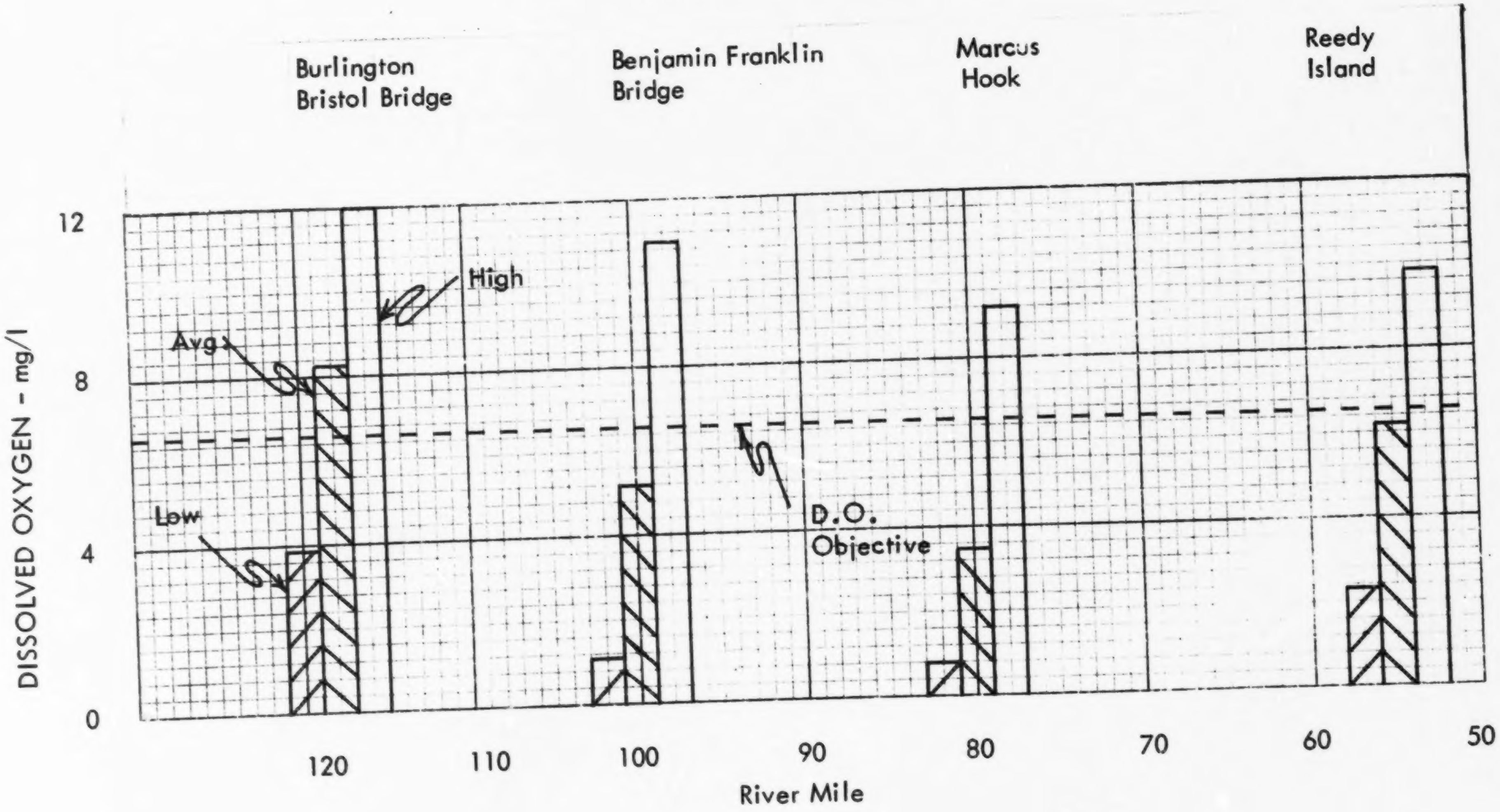


Figure 13

DISSOLVED OXYGEN - FISH PASSAGE PERIOD

September 16 - December 31, 1967-68

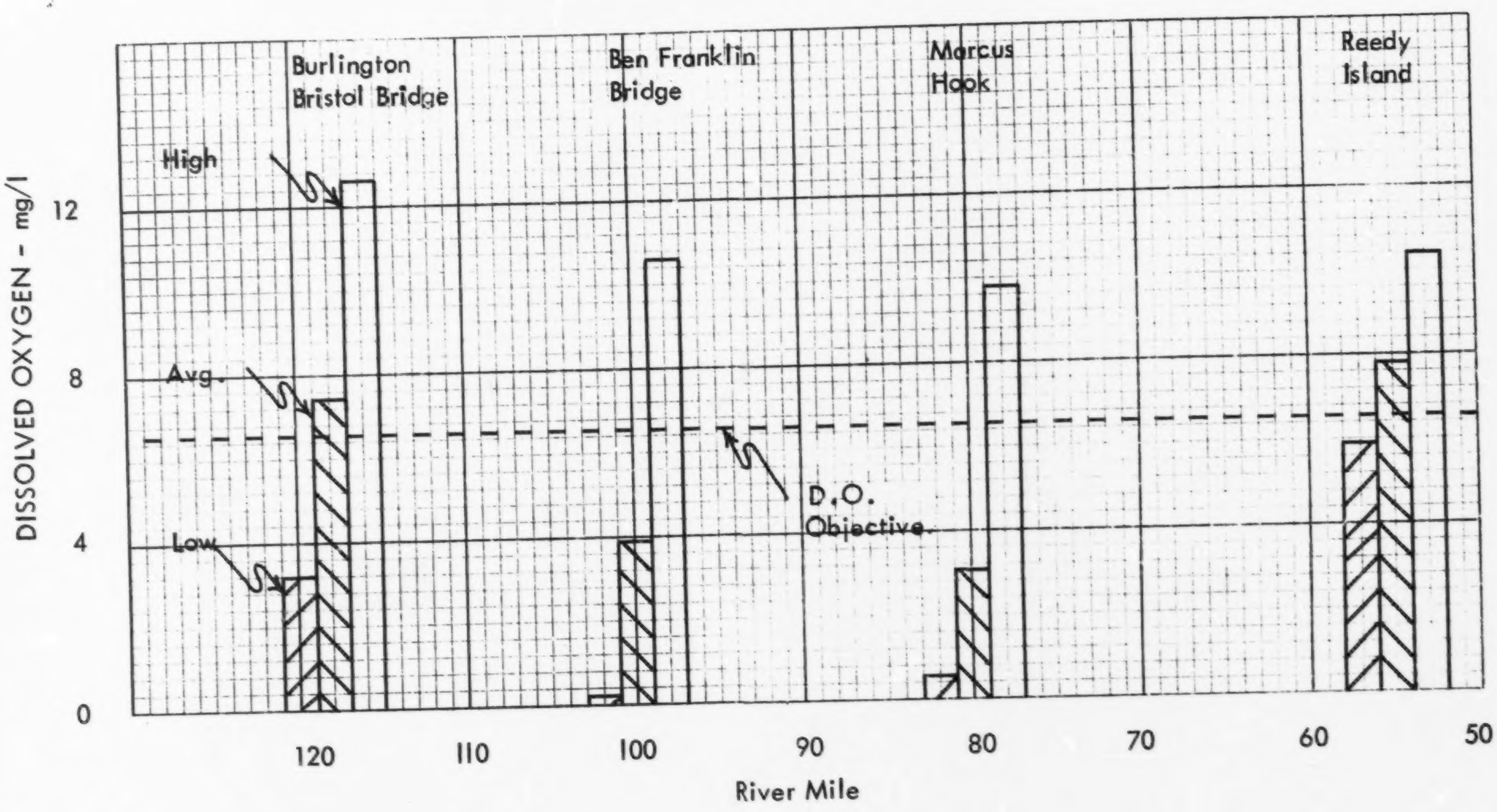


Figure 14

daily averages at these stations were from the boat run data, but in general, assuming that the daily average is one-half ppm less than the seasonal, the conclusion could be reached that the fish passage requirements are not being met throughout the Estuary under the present waste loadings to the Estuary.

b. Hardness. The standards for hardness has been established as maximum monthly means of 95 mg/l and 150 mg/l for Zones 2 and 3, respectively. The measurement of hardness is shown in Figure 15 at the Ben Franklin Bridge, just above the end of Zone 3. The monthly averages for the 1967-1968 study period had a maximum value of 90 mg/l in September which is below the maximum value permitted in the regulations.

c. Turbidity. The regulations call for a monthly mean of 40 units, or a maximum of 150 units of turbidity in any of the Estuary zones. Figure 16 showing the monthly averages of turbidity at four stations indicates only one value higher than 40 units occurring during the month of June at Reedy Island. At the other stations, all other values are below 30 units; therefore, a great percentage of the time the Estuary water has been below the maximum permitted turbidity levels. The minimum value was low as nine units and the range of the three stations besides Reedy Island was between 10 to 20 units.

d. Coliforms. Total and fecal coliform averages are shown in Figure 17 at four stations. The average values shown represent the data collected over the two year study with the highest counts, both fecal and total, occurring at the Ben Franklin Bridge. The total coliform count at this point was 45,000 per 100 ml and the fecal was approximately 10,000 per 100 ml. The ratio of total to fecal coliforms is not constant and at both ends of

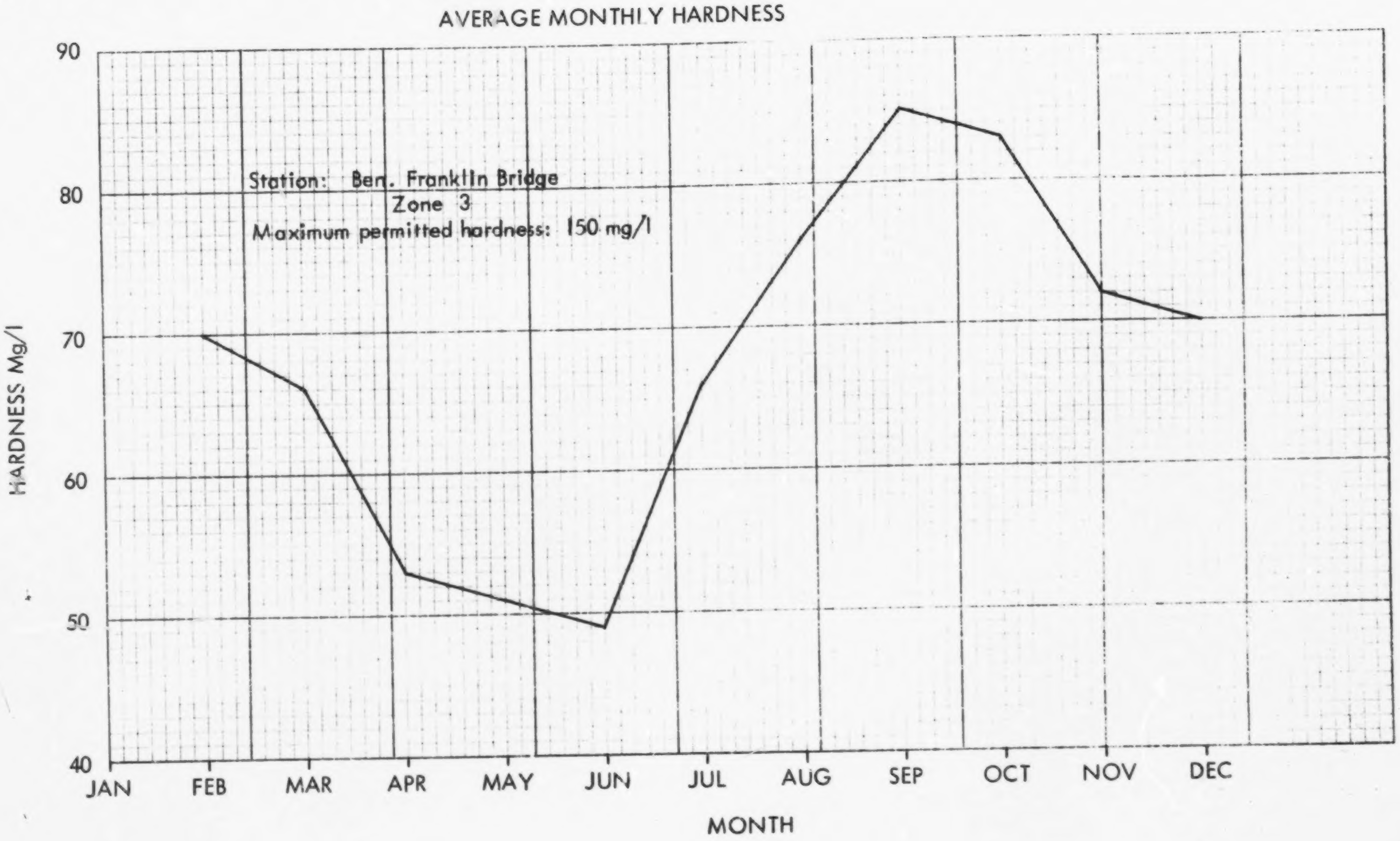

AVERAGE MONTHLY HARDNESS
Station: Ben. Franklin Bridge
Zone 3
Maximum permitted hardness: 150 mg/l
HARDNESS Mg/l
90
80
70
60
50
40
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 15

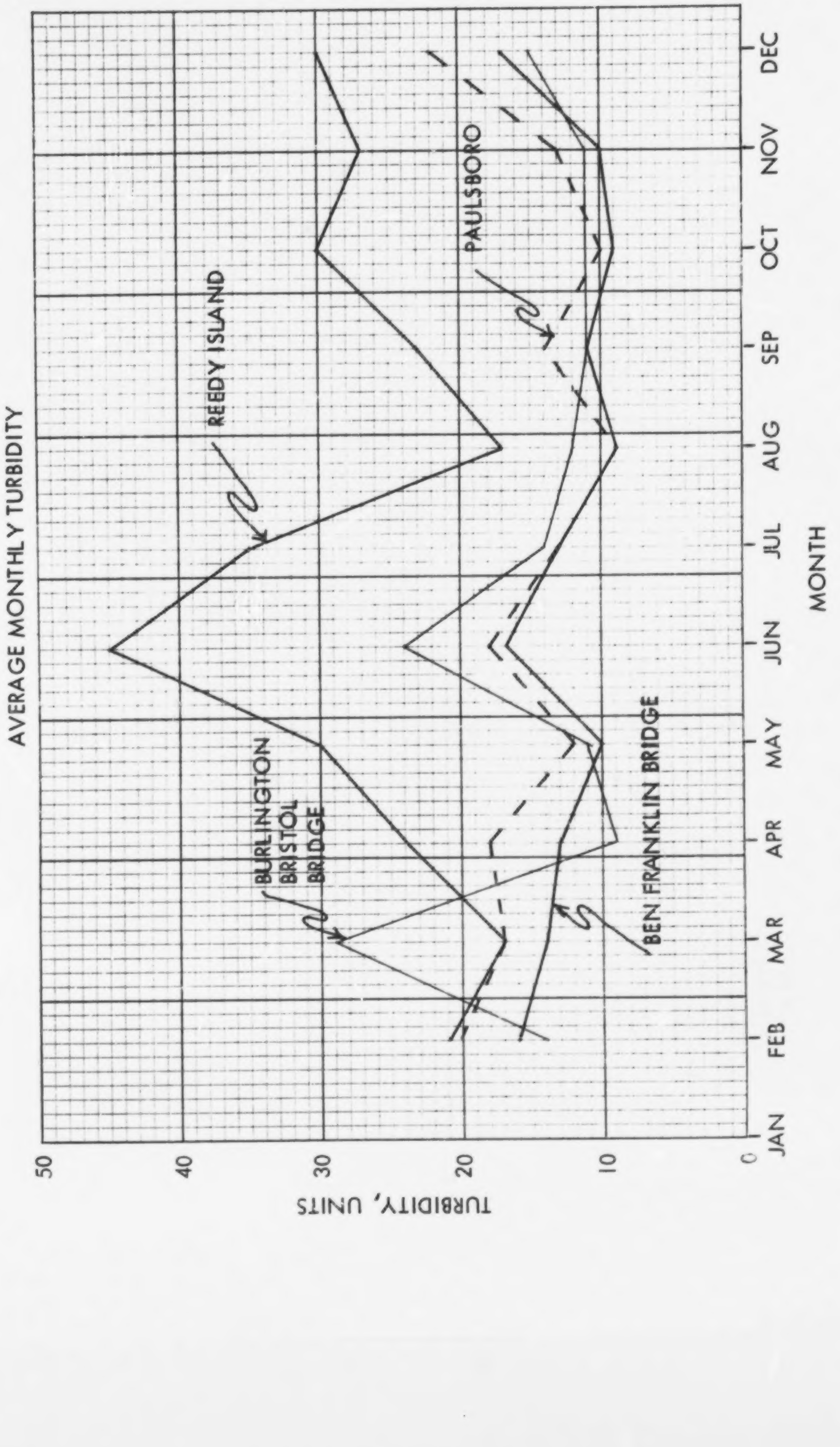
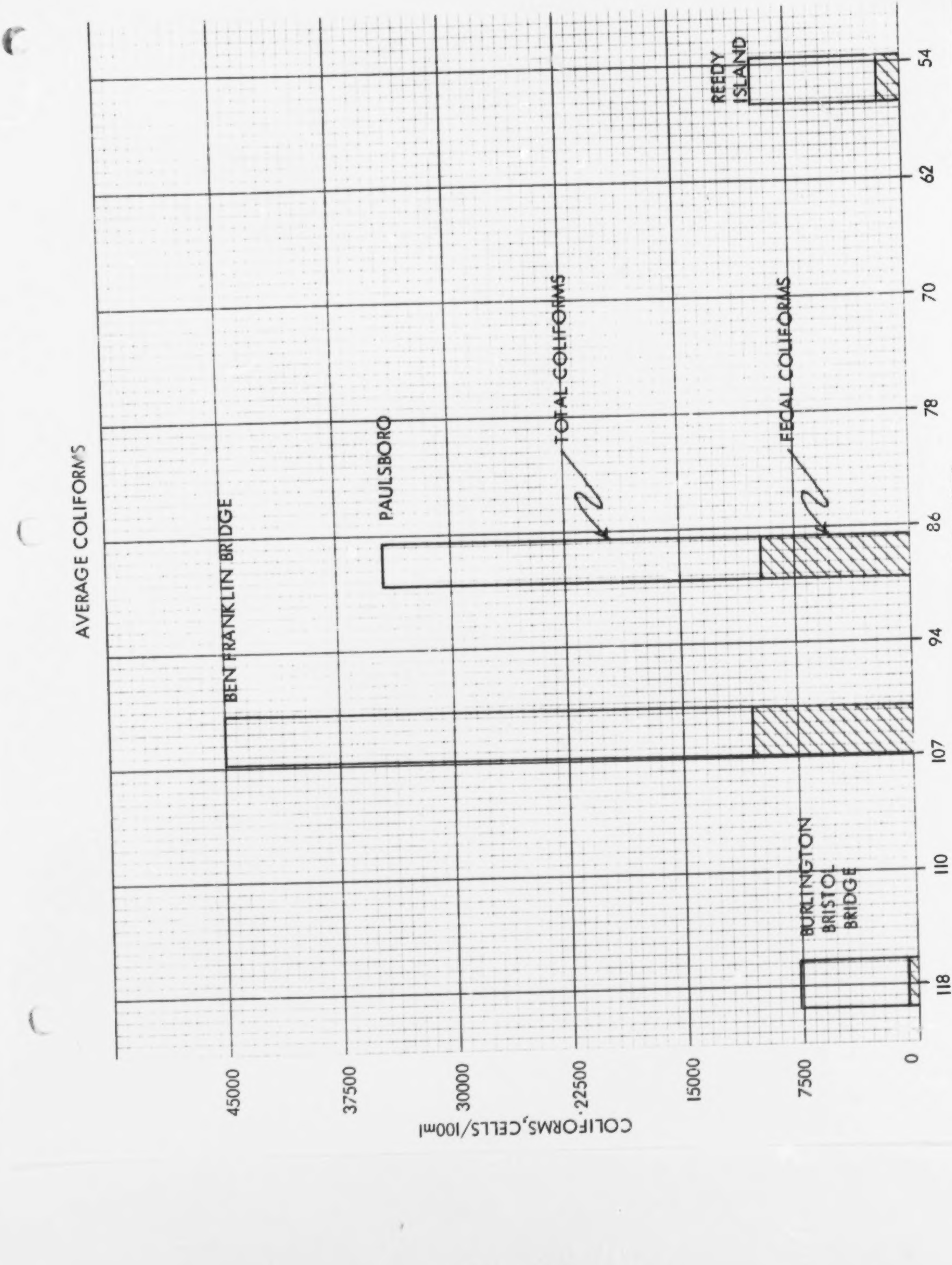

AVERAGE MONTHLY TURBIDITY
TURBIDITY, UNITS
0
10
20
30
40
50
MONTH
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
REEDY ISLAND
PAULSBORO
BURLINGTON BRISTOL BRIDGE
BEN FRANKLIN BRIDGE

Figure 16



AVERAGE COLIFORMS

the Estuary the fecal count is relatively low, less than 1500 per 100 ml.

e. Biochemical Oxygen Demand. Five-day BOD determinations were made of the river samples and are shown in Figure 18. Throughout the two-year study, BOD-5 ranged between 2 and 3 mg/l, except at Marcus Hook where the values were approximately 4.5 mg/l. With the flow variations shown previously, the stream BOD was fairly constant.

f. Chlorides. The requirements for chlorides in Zone 2 are a maximum permissible 15-day mean of 50 mg/l; Zone 3 has a maximum allowable of 200 mg/l and in Zone 4, 250 mg/l at R. M. 92.47. The specific conductance for April and October 1967-1968 study period is given in Figure 19 for Zones 2, 3, and 4. The right-hand ordinate is scaled for chlorides in mg/l. The October values for 1967-1968 are higher than the April values while the chloride concentrations in Zone 2 are below the maximum of 50 mg/l and in Zone 3 are below the maximum of 200 mg/l. At R. M. 92.0 in Zone 4 the October value of chlorides is less than 100 mg/l which is well below the maximum permitted of 250 mg/l.

g. Metals. The Regulations call for waters to be free of potentially toxic substances and "in no case shall concentrations of substances exceed those values given for rejection of water supplies in the United States Public Health Service (PHS) Drinking Water Standards." Based on these standards, the maximum permissible concentration of chromium in the Estuary is 0.05 mg/l. The mean chromium concentration at the five stations were all found to be below 0.1 mg/l, which is the detection limit of the test used.

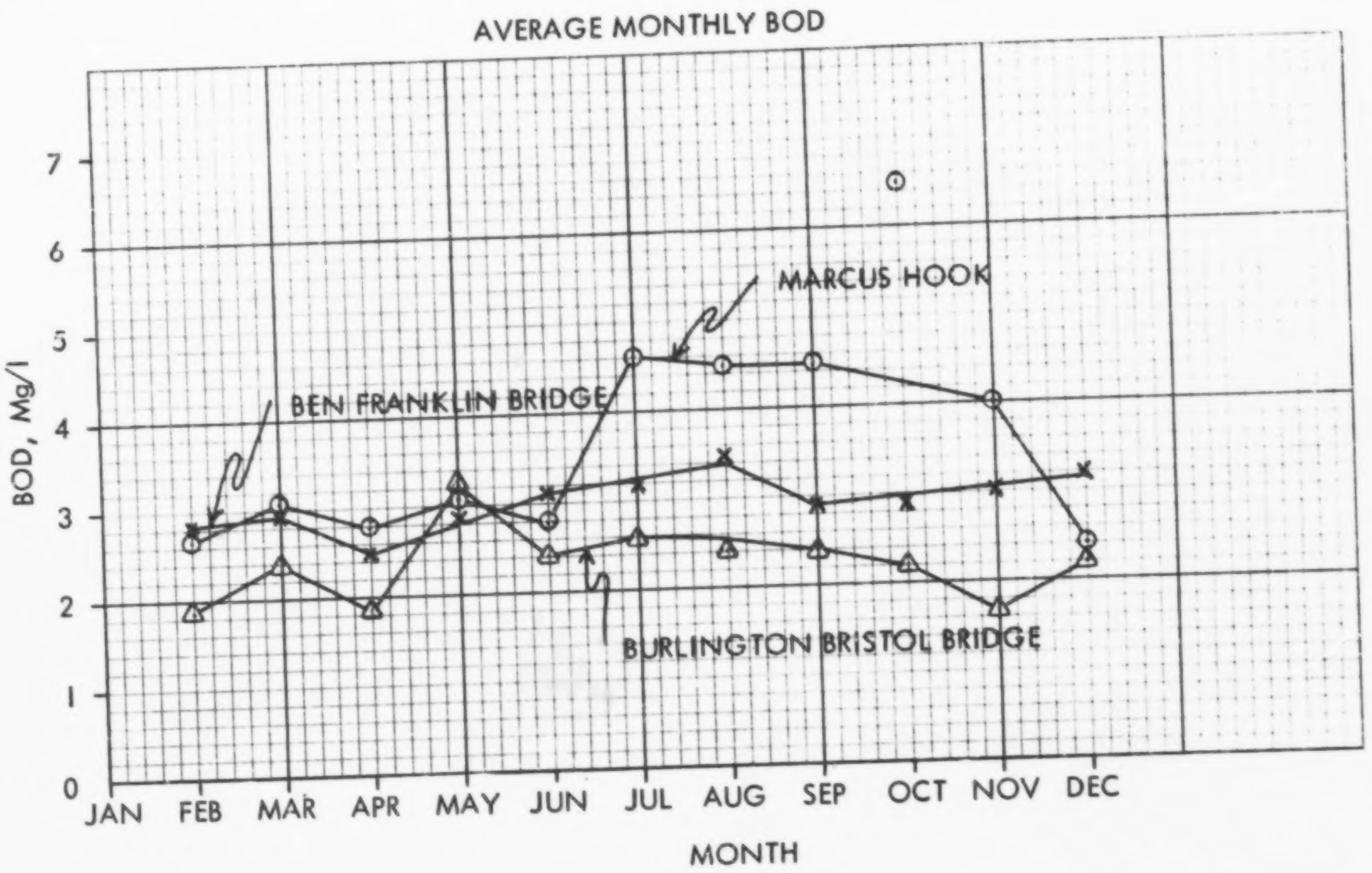
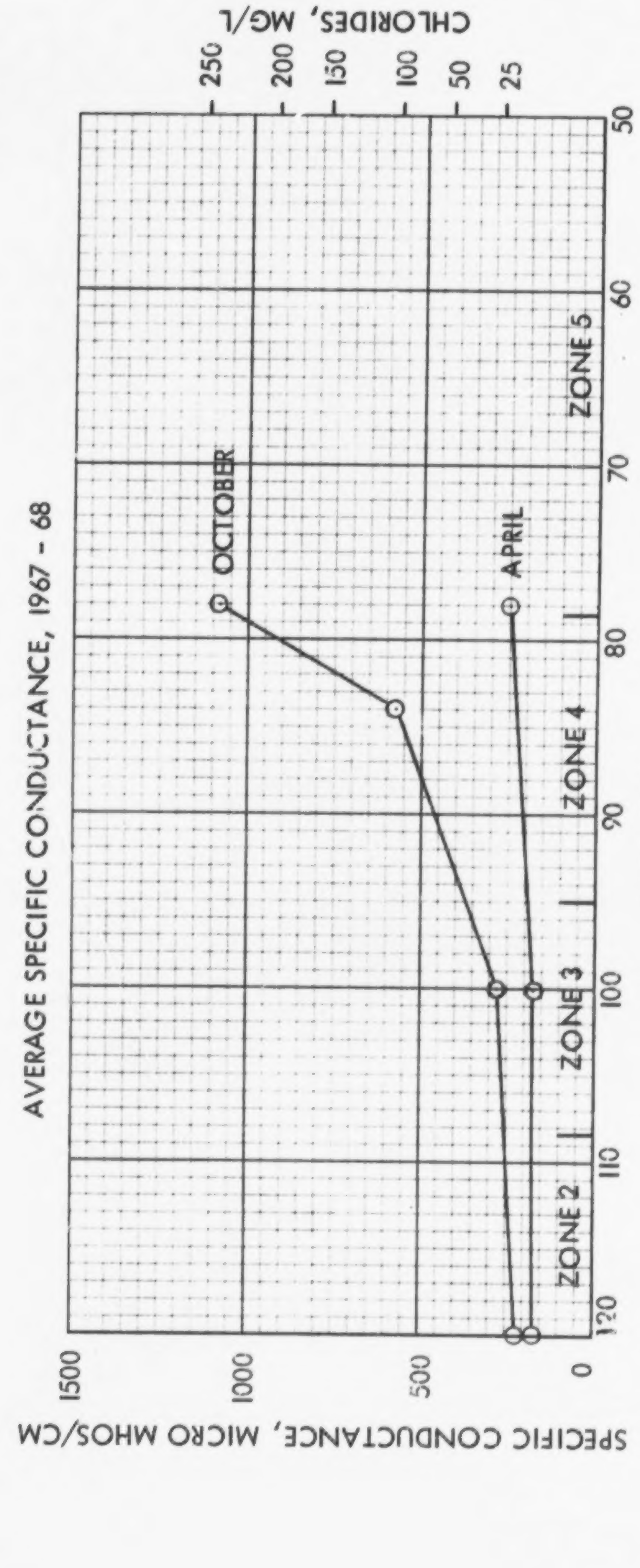

AVERAGE MONTHLY BOD
BOD, Mg/l
0
1
2
3
4
5
6
7
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH
MARCUS HOOK
BEN FRANKLIN BRIDGE
BURLINGTON BRISTOL BRIDGE

Figure 18



AVERAGE SPECIFIC CONDUCTANCE, 1967 - 68

Figure 19

Limits for other than toxic metals are not specified in the Regulations. Copper concentrations in the Estuary as represented by the five stations in Table 3 have been found to be less than 0.1 mg/l while the maximum concentration of zinc was 0.14 mg/l. The concentration of iron ranged from 0.71 to 1.50 mg/l. Nickel concentrations were found to be below 0.1 mg/l at the stations sampled.

h. Nitrates and Phosphates. The phosphate and nitrate concentrations for the 1968 steady state period are given in Figure 20. During this period, the nitrate nitrogen concentration was a maximum of 2.1 mg/l while the phosphate at R. M. 100 was a maximum of 1.6 mg/l. Sawyer (7) in a study of Wisconsin lakes concluded that a 0.30 mg/l concentration of inorganic nitrogen (N) and a 0.01 mg/l concentration of soluble phosphorus at the start of an active growing season could produce nuisance algal blooms. The concentration of nitrogen (N) in the Estuary was as high as 0.47 mgl. and that of phosphorus (P) was 0.52 mg/l. The Estuary nutrient levels then can be considered at or above concentrations found elsewhere to cause algal blooms.

AVERAGE NITRATES - PHOSPHATES, JULY - SEPTEMBER 1968

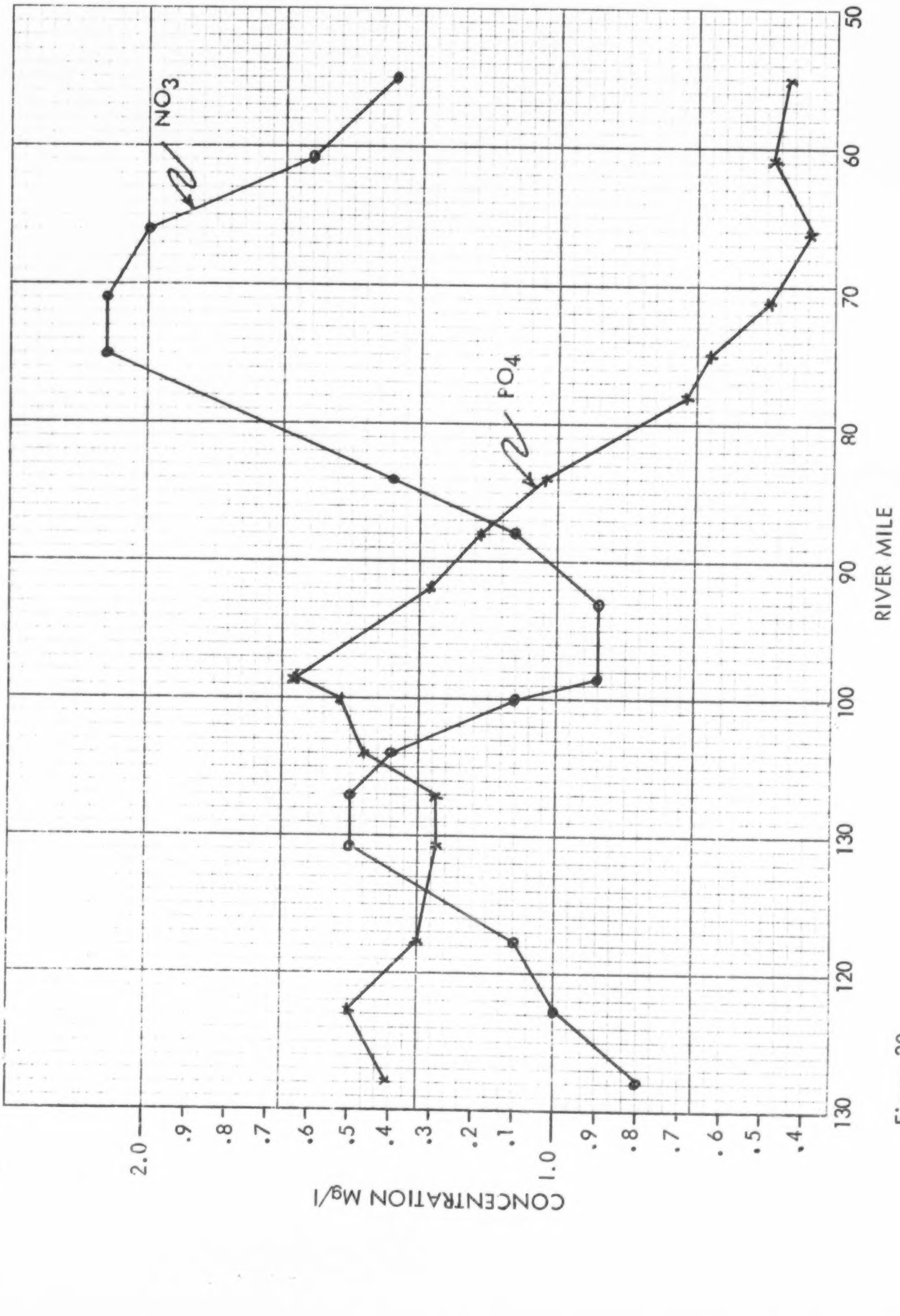


Figure 20

C. Validation of Mathematical Model for Dissolved Oxygen Predictions.

1. Estimation of Discharge Loads from 1967-1968 Sampling Data.

Analysis of the major municipal and industrial effluents has been and is currently being carried out under other, independently financed sampling contracts with member states. These contracts call for monthly sampling of biochemical oxygen demand, temperature, flow rates, and other parameters important to the determination of water quality. In determining the daily discharges from the industries and municipalities for the purpose of this report, the BOD-5 values were used in conjunction with a factor to convert to first stage ultimate oxygen demand (FSUOD). The factor used in this study, (FSUOD)/BOD-5, was 1.4. Where no BOD information was available, the most recently revised DECS estimates of FSUOD were used. Table 5 gives the compilation of the dischargers in their respective location by model section and their BOD-5 and FSUOD in pounds per day.

2. Determination of Dependent Variables for Model.

The steady-state period was determined from the flows at Trenton presented in the Water Resources Data for Pennsylvania. (8) The steady-state period in 1968 was determined to be between July 11 and September 10 with the average flow at Trenton of 4,572 cfs. To determine the first stage decay rates and the saturation values of dissolved oxygen, an average temperature of 26° C was used from Section 1 to Section 20 and 25° C from Section 21 to Section 30. These temperatures corresponded to respective decay rates of 0.45 and 0.40. Tables 6 and 7 show the inputs that were used for the first and second stage parameters, respectively.

Table No. 5

1968 Discharge Estimates from Sampling Data

BOD x 1.4

Section	Discharger	BOD #/day	La #/day	Section Total, #/day
1	Morrisville, Pa.	398	557	
1	Trenton, N. J.	7,667	10,733	11,290
2	Hamilton, N. J.	1,586	2,220	
2	Bordentown Township, N. J.	-	115	
2	U. S. Steel, Fairless Hills, Pa.	2,758	3,861	6,196
3	Florence, N. J.	-	345	
3	Paterson Parchment, Bristol, Pa.	863	1,207	
3	Lower Bucks MA, Pa.	2,034	2,847	
3	Penndel, Pa.	42	59	
3	Colordado Fuel & Iron	600	840	5,298
4	Bristol Borough, Pa.	540	756	
4	Bristol Township, Pa.	291	407	
4	Burlington La Gorce, N. J.	-	70	
4	Burlington City	212	297	
4	Burlington Township, N. J.	-	150	
4	Rohm & Haas, Bristol, Pa.	1,384	1,957	
4	Hercules Powder, Burlington, N. J.	-	210	3,827
5	Falls Township, Pa.	432	605	
5	Beverly, N. J.	-	265	
5	Burlington Army Ammunition Plant	437	612	
5	Tenneco Plastics, Burlington, N.J.	-	1,730	3,212
6	Willingboro, N. J.	-	490	
6	Riverside, N. J.	-	400	
6	Delran, N. J.	-	250	
6	B.F. Goodrich, Riverside, N. J.	-	340	1,480
7	-	-	-	
8	Riverton, N. J.	-	130	
8	Palmyra, N. J.	-	315	445
9	Cinnaminson SA, N. J.	-	575	
9	Allied Chemical Plastics, Phila., Pa.	96	134	709
10	Georgia-Pacific, Delair, N. J.	3,125	4,375	
10	Philadelphia-NE, Pa.	112,900	150,060	
10	Pennsauken Township, N. J.	2,625	3,675	
10	Camden-N. Plant, N. J.	-	2,740	160,850
11	National Sugar, Philadelphia, Pa.	7,996	11,194	11,194
12	-	-	-	

Table 5 Cont.

1968 Discharge Estimates from Sampling Data

Section	Discharger	BOD #/day	La #/day	Section Total, #/day
13	Camden-Main, N. J.	49,446	69,224	
13	MacAndrews & Forbes, Camden. N.J.	3,890	5,446	
13	Publicker, Philadelphia, Pa.	1,680	2,352	77,022
14	Philadelphia-SE, Pa.	92,479	129,470	
14	Bellmawr, N. J.	-	520	
14	Mt. Ephraim, N. J.	-	270	
14	Brooklawn, N. J.	-	425	
14	Gloucester City, N. J.	934	1,307	
14	Ruberoid, Gloucester City, N. J.	10,710	14,994	
14	Harshaw Chemical, Gloucester City, N. J.	-	1,860	
14	N. J. Zinc, Gloucester City, N. J.	2,309	3,232	152,078
15	Woodbury City, N. J.	2,025	2,835	
15	National Park, N. J.	-	620	
15	Atlantic Oil, Philadelphia, Pa.	17,834	24,967	
15	Gulf Oil, Philadelphia, Pa.	18,169	25,436	
15	Union Tank Car, Philadelphia, Pa.	-	3	
15	Youth Development Center, Philadelphia, Pa.	95	133	
15	Old Ft. Mifflin, Philadelphia, Pa.	-	7	
15	Army Engineers Dredging Depot, Phila., Pa.	-	3	
15	Texaco, Westville, N. J.	3,474	4,863	
15	U.S. Naval Base, Philadelphia, Pa.	-	480	
15	Shell Chemical, Woodbury, N. J.	-	4,810	64,157
16	Philadelphia-SW, Pa.	99,418	139,185	
16	Paulsboro, N. J.	1,146	1,604	
16	Mobil Oil, Paulsboro, N. J.	23,123	32,372	173,161
17	Gibbstown, N. J.	-	140	
17	Darby Creek SA, Pa.	3,378	4,729	
17	Muckinipattus, Pa.	1,092	1,528	
17	Tinicum, Pa.	52	73	
17	Central Delaware SA, Ridley, Pa.	2,174	3,043	
17	Eddystone Borough, Pa.	297	416	
17	Hercules Powder, Gibbstown, N.J.	1,612	2,256	
17	duPont-Repauno, Gibbstown, N.J.	53,122	74,370	
17	Scott Paper (foam), Eddystone, Pa.	-	145	86,700
18	Chester, Pa.	870	1,218	
18	Bryton Chemical, Philadelphia, Pa.	142	198	
18	Congoleum Nairn, Philadelphia, Pa.	226	316	
18	Scott Paper, Chester, Pa.	8,028	11,239	
18	Pa. Industrial Chemical, Chester, Pa.	18	25	
18	Sinclair, Trainer, Pa.	12,347	17,285	
18	FMC, Marcus Hook, Pa.	-	1,595	31,876

Table 5 Cont.

1968 Discharge Estimates from Sampling Data

Section	Discharger	BOD #/day	La #/day	Section Total, #/day
19	Marcus Hook, Pa.	933	1,306	
19	Monsanto, Bridgeport, N. J.	21,191	29,667	
19	Sun Oil-Sunolin, Marcus Hook, Pa.	31,354	43,895	
19	Allied Chemical, Claymont, Del.	5,352	7,494	
19	Phoenix Steel, Claymont, Del.	-	90	82,452
20	-	-	-	-
21	Penns Grove, N. J.	673	942	
21	Wilmington, Del.	36,485	51,079	
21	duPont-Carney, Penns Grove, N. J.	16,860	23,604	
21	duPont-Edgemoor, Del.	3,691	5,167	80,792
22	duPont-Chambers, Deepwater, N. J.	49,938	69,913	
22	Atlas Chemical, New Castle, Del.	51,408	71,971	141,884
23	Upper Penns Neck, N. J.	-	1,110	
23	Pennsville, N. J.	335	469	1,579
24	-	-	-	-
25	-	-	-	-
26	Getty Oil, Delaware City, Del.	8,571	12,000	12,000
27	Delaware City, Del.	-	170	170
28	Salem City, N. J.	1,365	1,911	1,911

3-17-70

TABLE 6

FIRST STAGE COMPUTER INPUT

Section	Flow C.F.S.	Rea. Rate 1.0/day	Decay Rate 1.0/day	Volume CF* 10^6	Diff. Rate MI^2/day	Area 1000*FT^2	L-Loads Lb./day	F-Loads Lb./day	D.O. Sat. MG/L
1	4572.	0.65	0.45	242.	0.40	6.50	97643.	22280.	8.2
2	4745.	0.36	0.45	364.	0.40	15.80	10292.	8622.	8.2
3	4892.	0.23	0.45	460.	0.40	21.40	5537.	4140.	8.2
4	4901.	0.23	0.45	532.	0.40	24.60	4981.	2700.	8.2
5	4946.	0.16	0.45	636.	0.40	28.50	5221.	4800.	8.2
6	5069.	0.22	0.45	756.	0.40	34.10	8113.	5040.	8.2
7	4887.	0.22	0.45	455.	0.90	41.40	877.	890.	8.2
8	4916.	0.22	0.45	504.	1.60	49.60	2827.	2125.	8.2
9	4955.	0.16	0.45	533.	2.20	51.20	9329.	2250.	8.2
10	4980.	0.16	0.45	582.	2.70	55.40	165295.	2250.	8.2
11	5294.	0.16	0.45	630.	3.30	60.90	28980.	5760.	8.2
12	5352.	0.12	0.45	655.	3.80	65.00	4480.	1350.	8.2
13	5352.	0.12	0.45	694.	4.40	66.00	84528.	3240.	8.2
14	5363.	0.19	0.45	805.	4.50	72.70	156804.	3960.	8.2
15	5454.	0.19	0.45	1860.	4.60	88.30	105960.	14700.	8.2
16	6425.	0.26	0.45	2030.	4.80	98.00	176512.	6750.	8.2
17	6926.	0.19	0.45	2184.	5.00	104.90	91693.	11475.	8.2
18	7078.	0.17	0.45	2396.	5.30	113.40	34916.	7200.	8.2
19	7177.	0.17	0.45	2692.	5.50	126.30	83783.	16200.	8.2
20	7220.	0.13	0.45	2932.	5.80	142.80	437.	15750.	8.2
21	7271.	0.18	0.40	1512.	6.00	150.40	101588.	6930.	8.4
22	7707.	0.18	0.40	1574.	6.20	151.90	141949.	6000.	8.4
23	7707.	0.18	0.40	1698.	6.30	162.90	1647.	13050.	8.4
24	7707.	0.17	0.40	1792.	6.40	176.80	102.	11000.	8.4
25	7707.	0.17	0.40	1850.	6.50	181.70	210.	9300.	8.4
26	7714.	0.18	0.40	1924.	6.60	188.40	12345.	12000.	8.4
27	7730.	0.18	0.40	2054.	6.80	196.40	272.	15000.	8.4
28	7738.	0.18	0.40	2248.	6.90	214.50	4763.	15000.	8.4
29	7831.	0.19	0.40	4896.	7.00	235.00	974.	0.	8.4
30	7862.	0.16	0.40	5620.	7.20	254.00	924.	0.	8.4
31	7909.	0.0	0.0	0.	7.50	307.40	0.	0.	8.4

TABLE τ

SECOND STAGE COMPUTER INPUT

Section	Flow C.F.S.	Rea. Rate 1.0/day	Decay Rate 1.0/day	Volume CF* 10^6	Diff. Rate MI^2/day	Area 1000*FT^2	L-Loads Lb./day	F-Loads Lb./day	D.O. Sat. MG/L
1	4572.	0.65	0.00	242.	0.40	6.50	122047.	-34500.	0.0
2	4745.	0.36	0.00	364.	0.40	15.80	14808.	0.	0.0
3	4892.	0.23	0.00	460.	0.40	21.40	10479.	0.	0.0
4	4901.	0.23	0.03	532.	0.40	24.60	6304.	0.	0.0
5	4946.	0.16	0.02	636.	0.40	28.50	5014.	0.	0.0
6	5069.	0.22	0.01	756.	0.40	34.10	10238.	0.	0.0
7	4887.	0.22	0.01	455.	0.90	41.40	969.	0.	0.0
8	4916.	0.22	0.01	504.	1.60	49.60	4609.	0.	0.0
9	4955.	0.16	0.05	533.	2.20	51.20	13088.	0.	0.0
10	4980.	0.16	0.05	582.	2.70	55.40	94512.	0.	0.0
11	5294.	0.16	0.0	630.	3.30	60.90	26553.	0.	0.0
12	5352.	0.12	0.0	655.	3.80	65.00	6272.	0.	0.0
13	5352.	0.12	0.0	694.	4.40	66.00	55470.	0.	0.0
14	5363.	0.19	0.0	805.	4.50	72.70	114618.	0.	0.0
15	5454.	0.19	0.01	1860.	4.60	88.30	53315.	0.	0.0
16	6425.	0.26	0.04	2030	4.80	98.00	150434.	0.	0.0
17	6926.	0.19	0.04	2184.	5.00	104.90	61910.	0.	0.0
18	7078.	0.17	0.08	2396.	5.30	113.40	14106.	0.	0.0
19	7177.	0.17	0.10	2692.	5.50	126.30	13538.	0.	0.0
20	7220.	0.13	0.10	2932.	5.80	142.80	437.	0.	0.0
21	7271.	0.18	0.10	1512.	6.00	150.40	76751.	0.	0.0
22	7707.	0.18	0.10	1574.	6.20	151.90	65.	0.	0.0
23	7707.	0.18	0.10	1698.	6.30	162.90	1433.	0.	0.0
24	7707.	0.17	0.10	1792.	6.40	176.80	102.	0.	0.0
25	7707.	0.17	0.10	1850.	6.50	181.70	210.	0.	0.0
26	7714.	0.18	0.10	1924.	6.60	188.40	9027.	0.	0.0
27	7730.	0.18	0.10	2054.	6.80	196.40	602.	0.	0.0
28	7738.	0.18	0.10	2248.	6.90	214.50	4167.	0.	0.0
29	7831.	0.19	0.10	4896.	7.00	235.00	974.	0.	0.0
30	7862.	0.16	0.10	5620.	7.20	254.00	924.	0.	0.0
31	7909.	0.0	0.00	0.	7.50	307.40	0.	0.	0.0

The second stage (nitrogenous) loads from the Estuary dischargers and those coming from tributaries were those estimated by the DECS. The Estuary discharge, beginning at Trenton, were proportioned to the flows used for 1964 discharges. The nitrogenous loads in this model were used in the section that they were discharged and were not shadowed or lagged as was done by the DECS. Instead, the second stage reaction rates were adjusted so that the predicted 1964 dissolved oxygen profile fitted the observed profile for the steady-state period of 1964.

3. Prediction of Dissolved Oxygen Profiles.

The verification run in which the predicted curve was matched with the observed of 1964 is given in Figure 21. Figure 22 shows the predicted and observed dissolved oxygen profile of the steady-state period for 1968. Between sections 12 and 19, the two curves are in very close agreement while in the upper end of the Estuary, the predicted curve tends to be higher than the observed profile. The same is true in the lower end of the Estuary. Because the estimates of first stage loadings were based on an assumed first stage to 5-day BOD ratio, some differences between the predicted and observed plots were expected. However, the closeness of fit at the most critical part of the profile in Zones 3 and 4 indicates the predictive power of this model for periods other than those used for verification.

DISSOLVED OXYGEN MODEL VERIFICATION FOR 1964

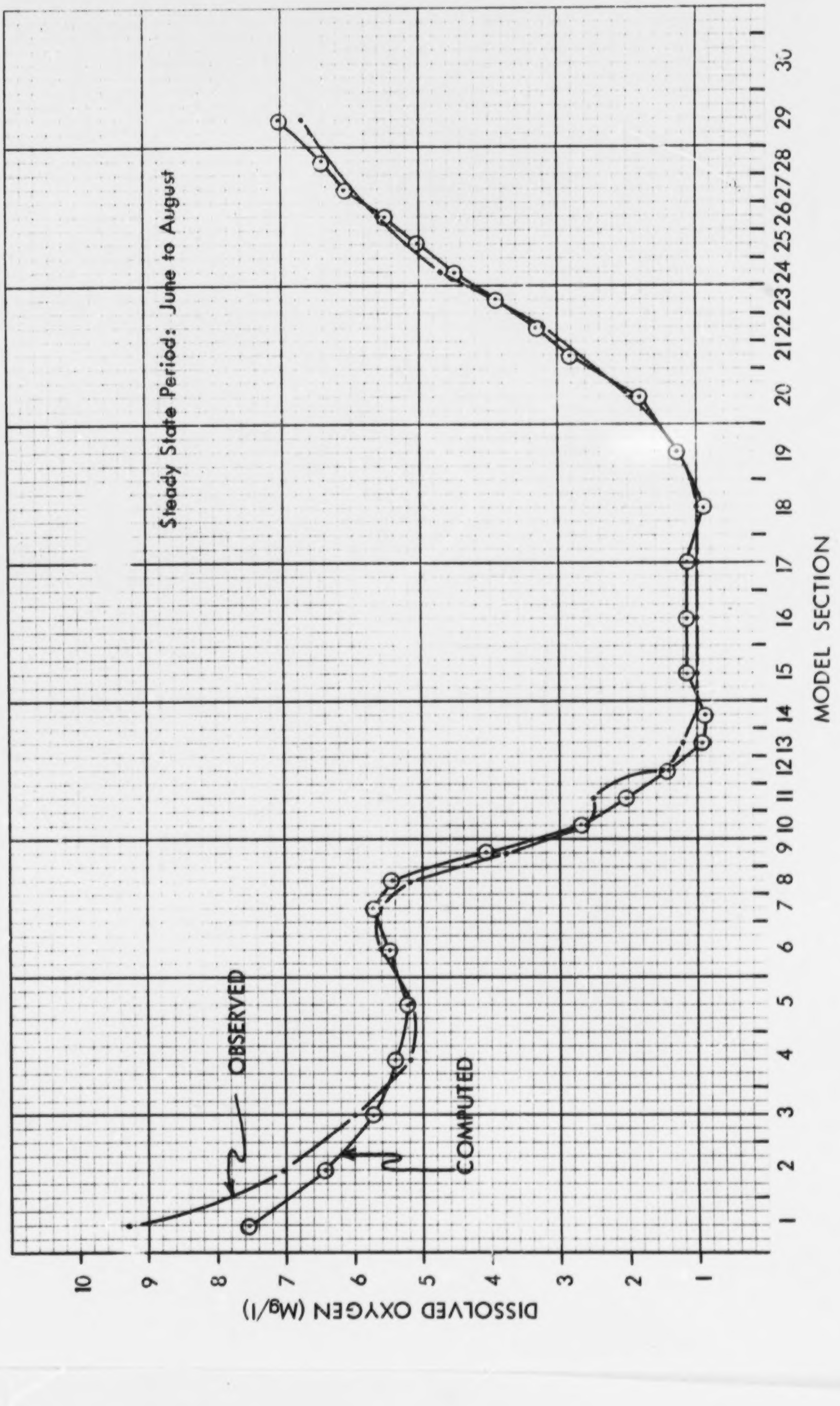


Figure 21

DISSOLVED OXYGEN MODEL VERIFICATION FOR 1968

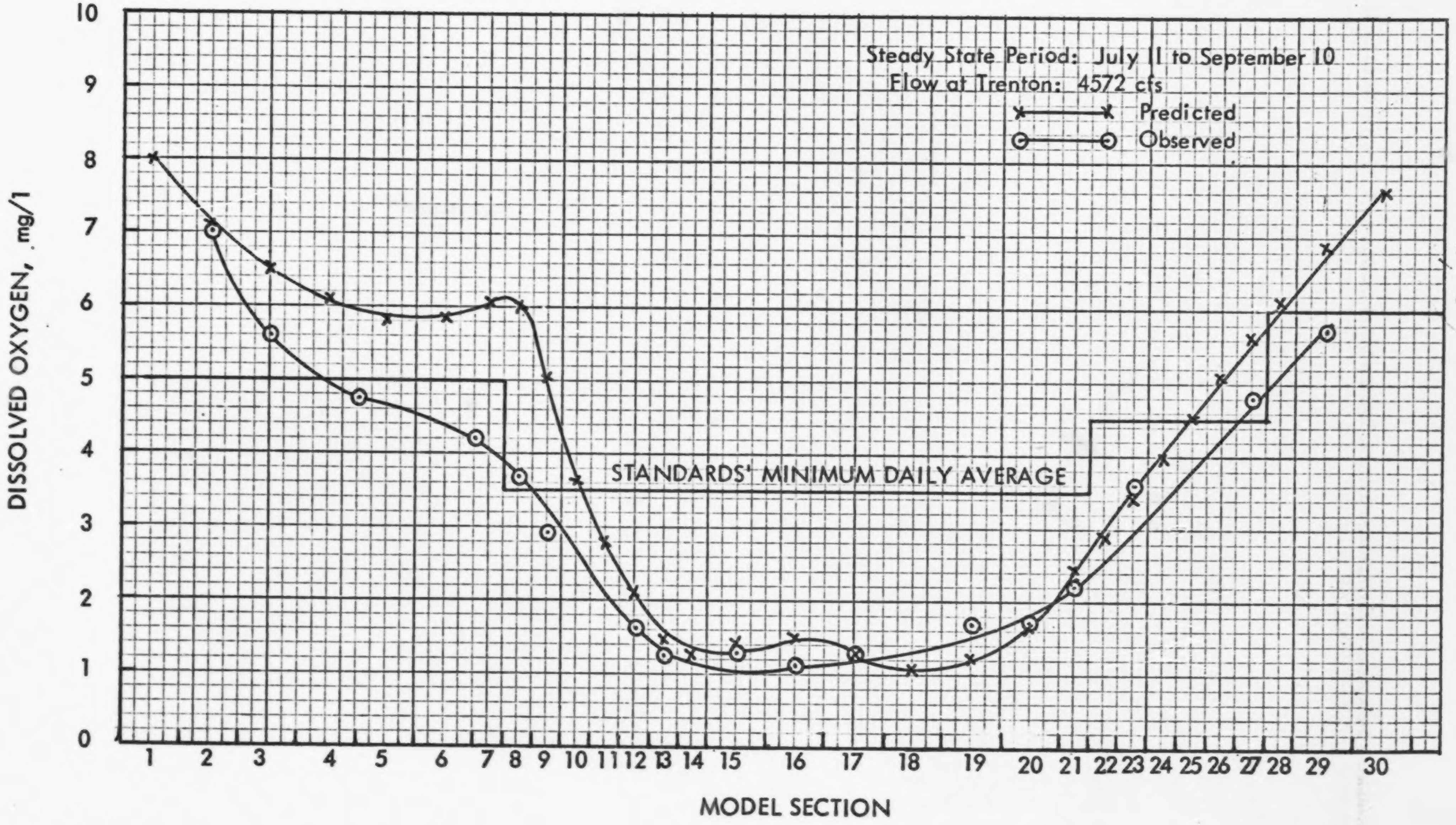


Figure 22

D. Use of Time-Varying Model.

1. Prediction of Dissolved Oxygen. The time-varying mathematical model was also developed by the DECS. One of the first time-varying models that was formulated and programmed was called DECS II and was used during the drought of 1965 in the Delaware River Basin to predict both dissolved oxygen distributions, and especially due to the drought, levels of chlorides in the Estuary which were increasing due to the low flow conditions. A more refined time-varying model, DECS III, was developed so that up to 150 sections could be included and also that many more water quality parameters could be handled. (9) However, for the Delaware Estuary model, the number of sections was kept at 30, the same as in the steady-state version.

The principles that the time-varying model are based upon are the same as in the steady-state version, except that the change of concentration of a substance with time is not zero. In both, two mass balance equations representing the two subsystems of biochemical oxygen demand and dissolved oxygen concentrations are solved by numerical methods. The time-varying model allows more flexibility in the calculation of some of the parameters such as reaeration coefficients which are based on depth and velocity of flow, and the first stage decay constants based primarily on temperature. Other inputs, such as Estuary flow, also are flexible and could be entered either as independent flows for each segment or as an initial flow with differential flows being added by the computer. The interval period can be on a daily, weekly, or monthly basis. A time interval of 5 days was used for insertion of the input data and the prediction of the dissolved oxygen levels.

The time-varying model as initially developed by DECS was not fully verified for dissolved oxygen predictions. Extensive work has been done with this model for the 1964 year so that reliable predictions for dissolved oxygen in the Estuary could be made. On the basis of 5-day intervals, the computed dissolved oxygen profiles at Sections 4 and 12 were compared to observed boat run and monitor data. Some of the results of this verification are shown in Figures 23 and 24.

2. Prediction of Salinity. Salinity, a conservative substance, can be predicted with this model if the proper modifications are made. If the decay mechanism is omitted in the BOD system of the model, other conservative substances such as alkalinity, pH, and chlorides can be projected. The chloride levels are dependent on the inputs from the lower or upper boundaries and the physical and hydraulic characteristics of the Estuary.

The use of the time-varying model for predicting chlorides is important because of the large water intake to the Philadelphia area at the Torresdale water treatment plant. The Regulations' maximum permitted chloride level at R. M. 92.47, which is 18 miles below the plant, is 250 mg/l. The time-varying model is being extended for use down to Ship John Light (R.M. 36.9) at the lower end of the Estuary for chloride predictions.

Figures 25 and 26 show some of the results of the 1964 verifications at stations for chloride levels for July 10 and October 20, 1964. The computed and observed chloride profiles agreed very well.

OBSERVED VS COMPUTED DISSOLVED OXYGEN CONCENTRATIONS

Burlington Bristol Bridge, Section 4

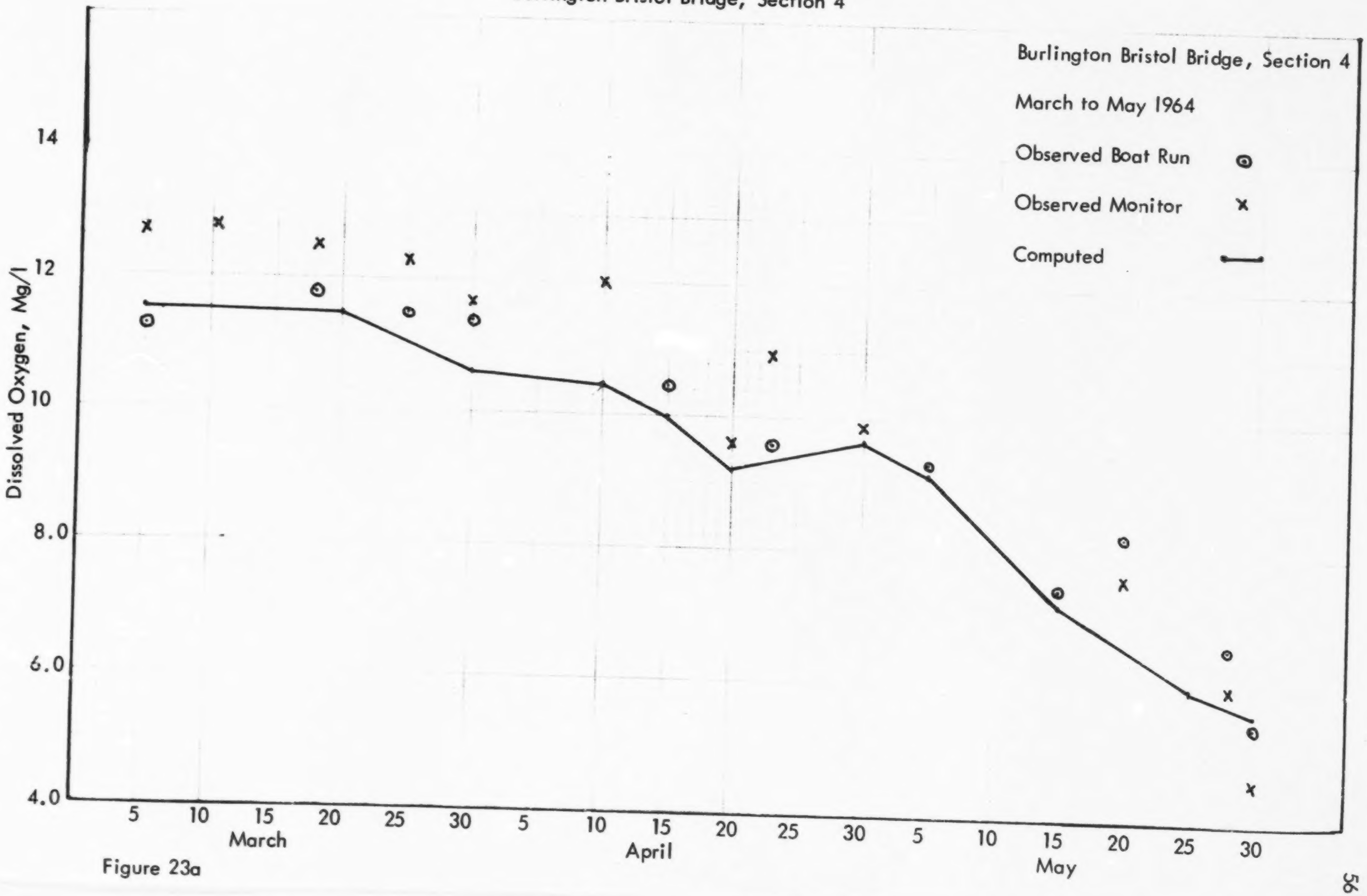


Figure 23a

OBSERVED VS COMPUTED DISSOLVED OXYGEN CONCENTRATIONS

Burlington Bristol Bridge, Section 4

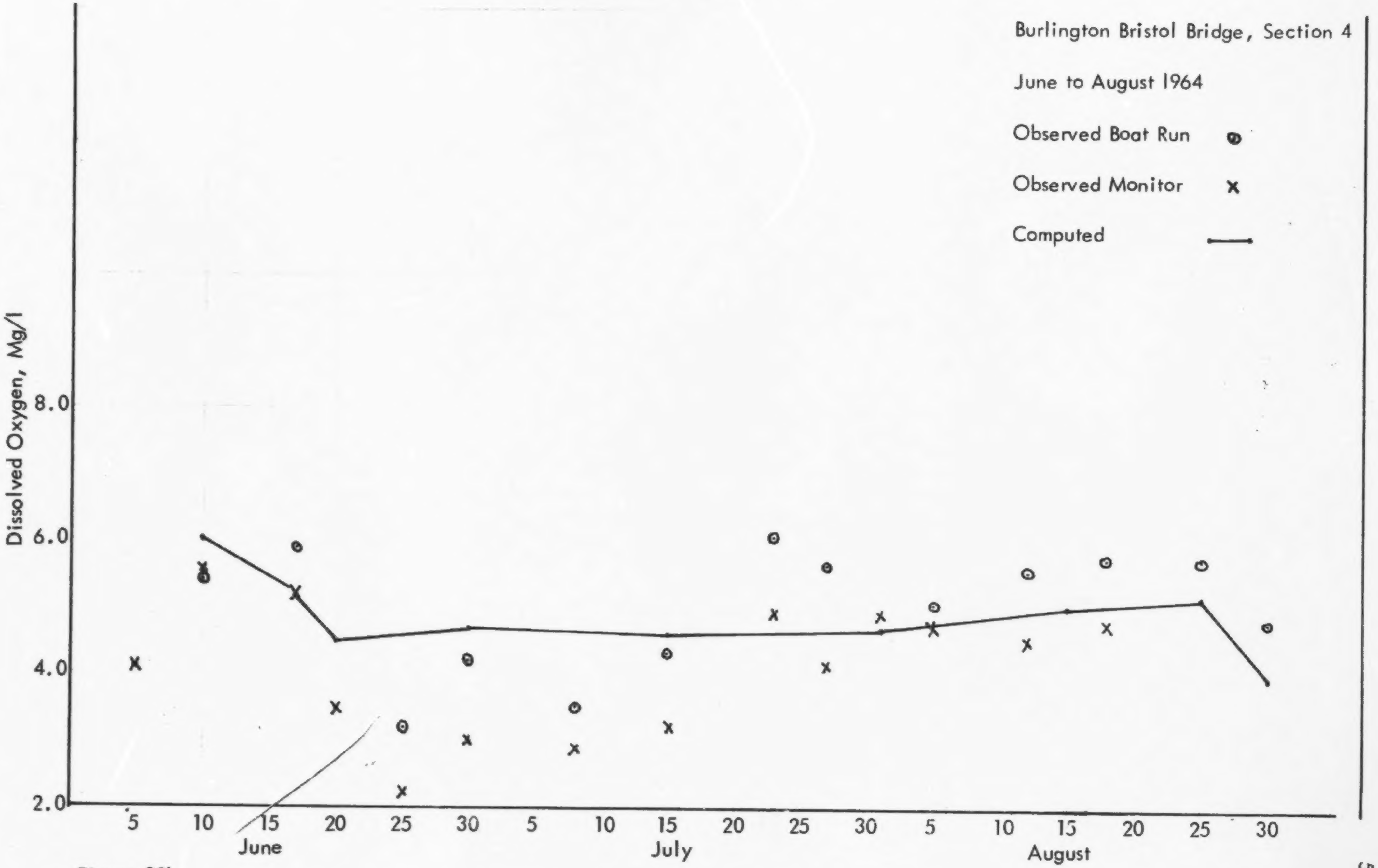


Figure 23b

OBSERVED VS COMPUTED DISSOLVED OXYGEN CONCENTRATIONS

Burlington Bristol Bridge, Section 4

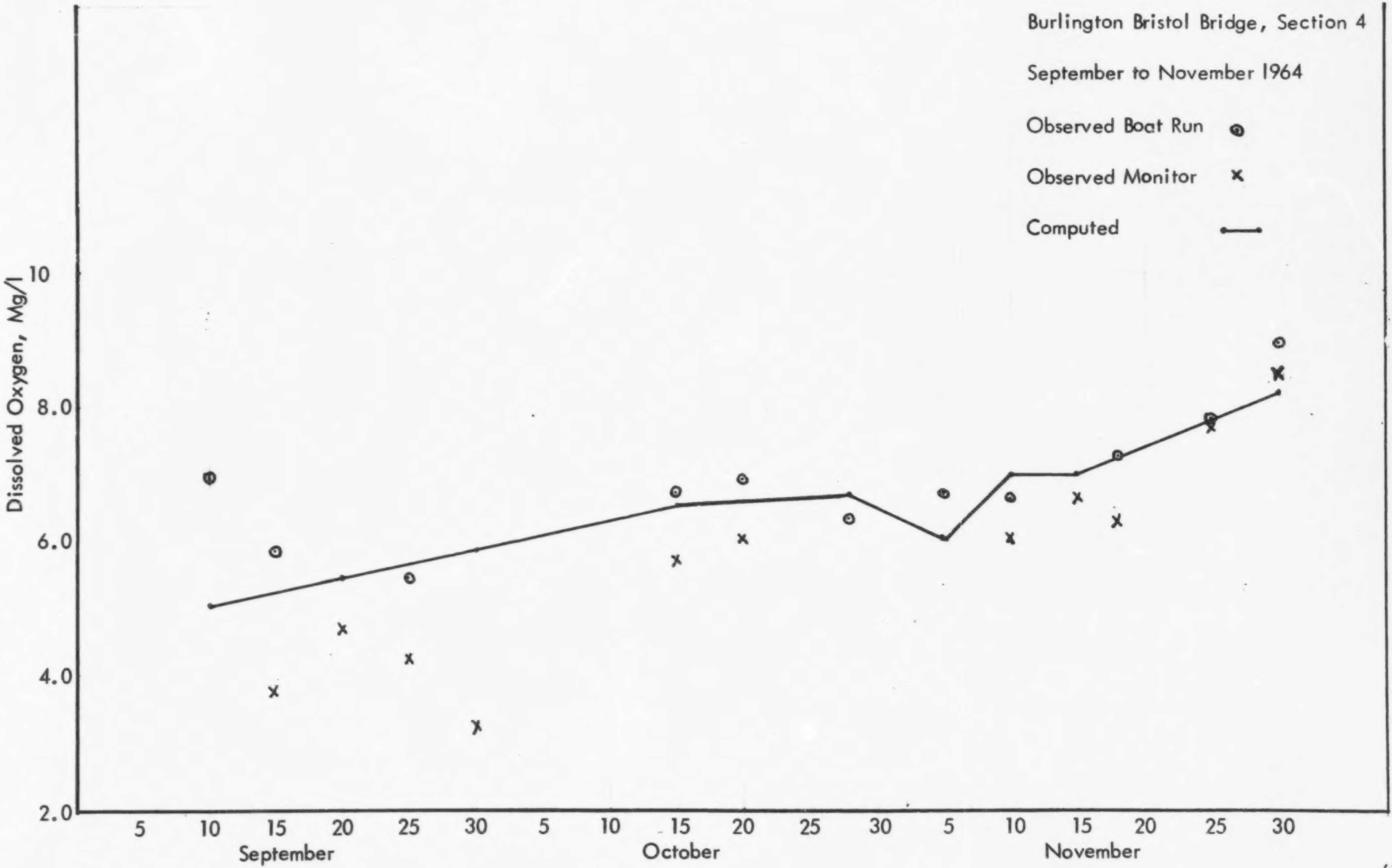


Figure 23c

OBSERVED VS COMPUTED DISSOLVED OXYGEN CONCENTRATIONS

Benjamin Franklin Bridge, Section 12

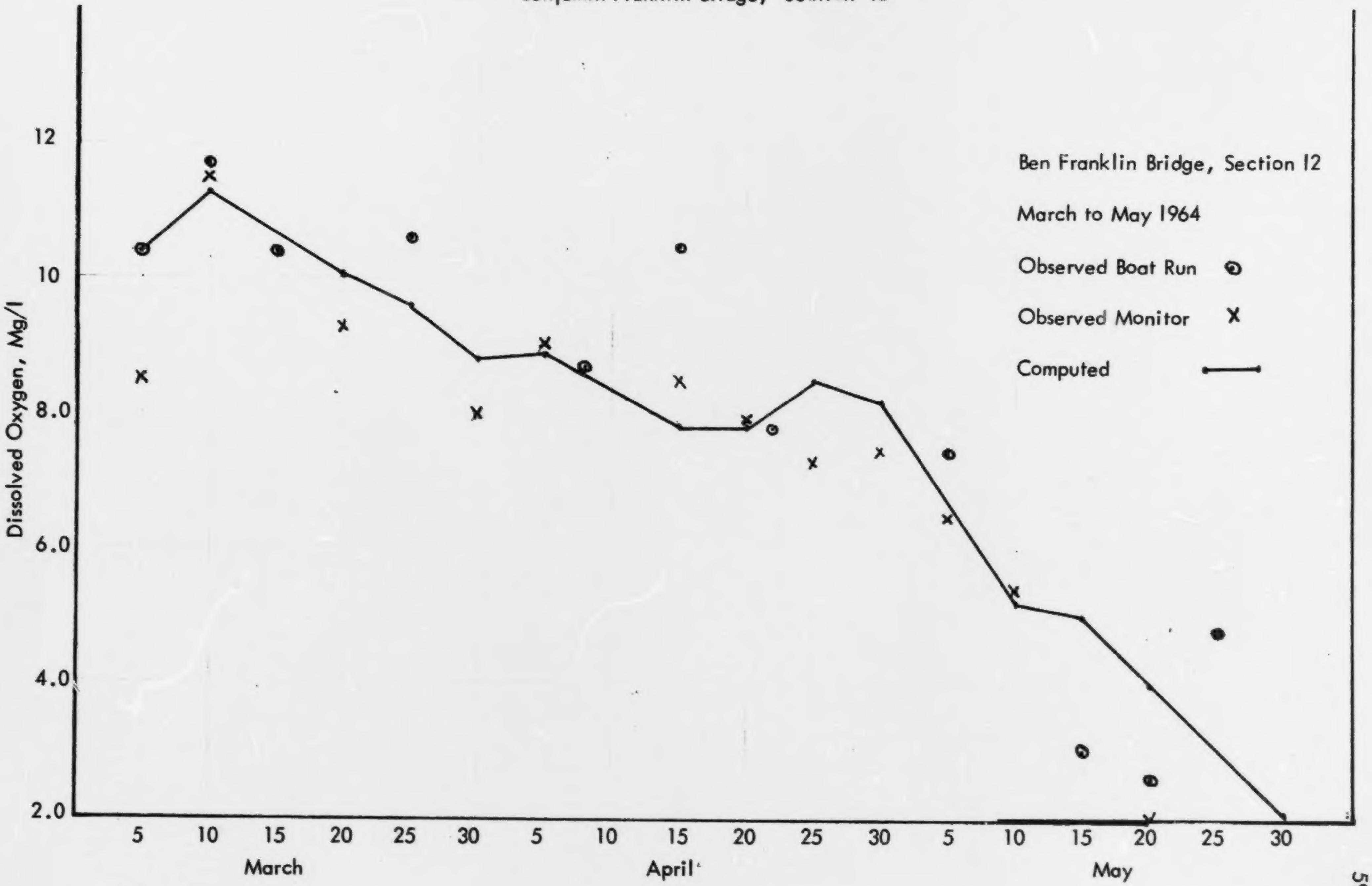


Figure 24a

OBSERVED VS COMPUTED DISSOLVED OXYGEN CONCENTRATIONS

Benjamin Franklin Bridge, Section 12

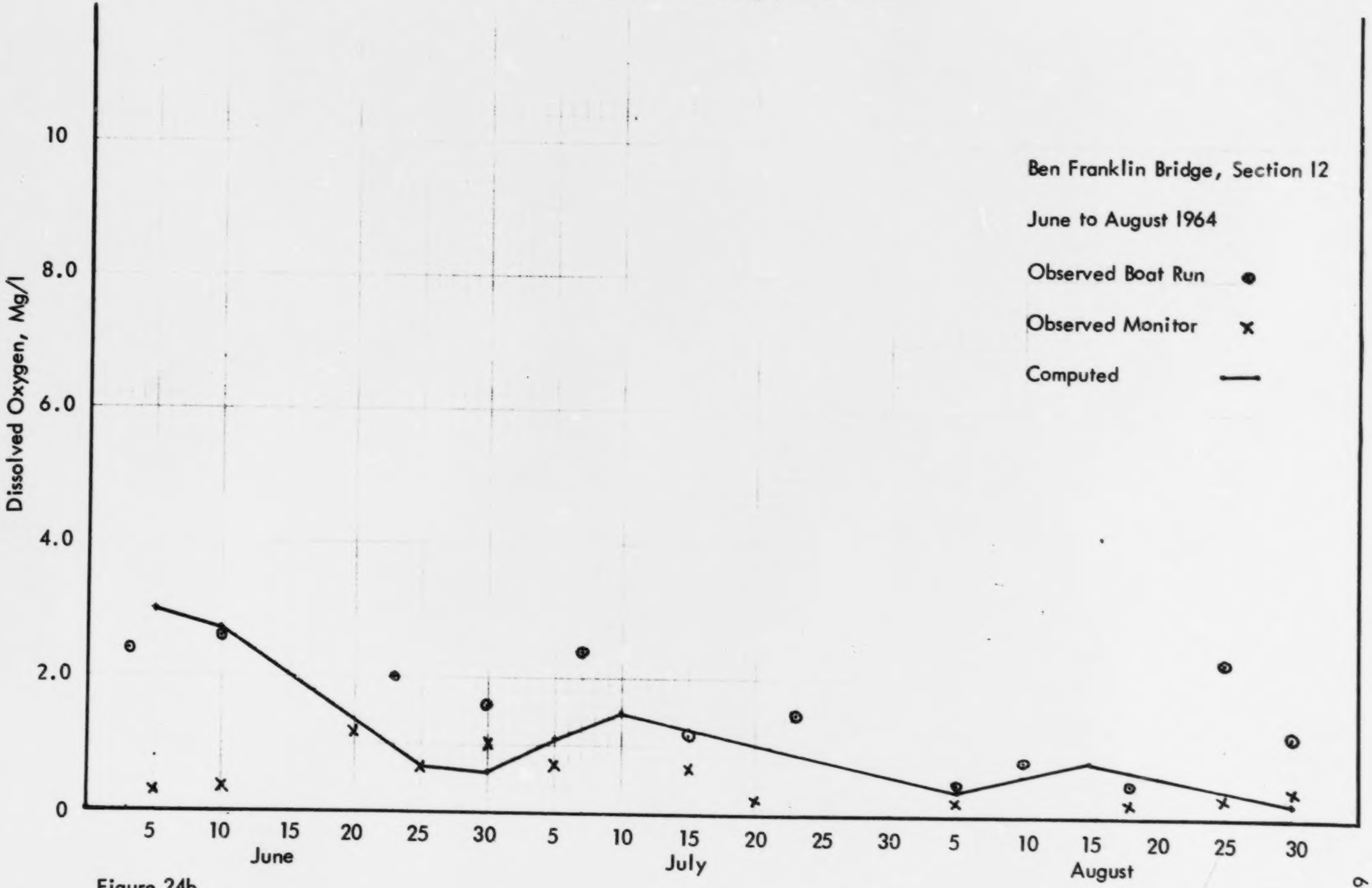


Figure 24b

OBSERVED VS COMPUTED DISSOLVED OXYGEN CONCENTRATIONS

Benjamin Franklin Bridge, Section 12

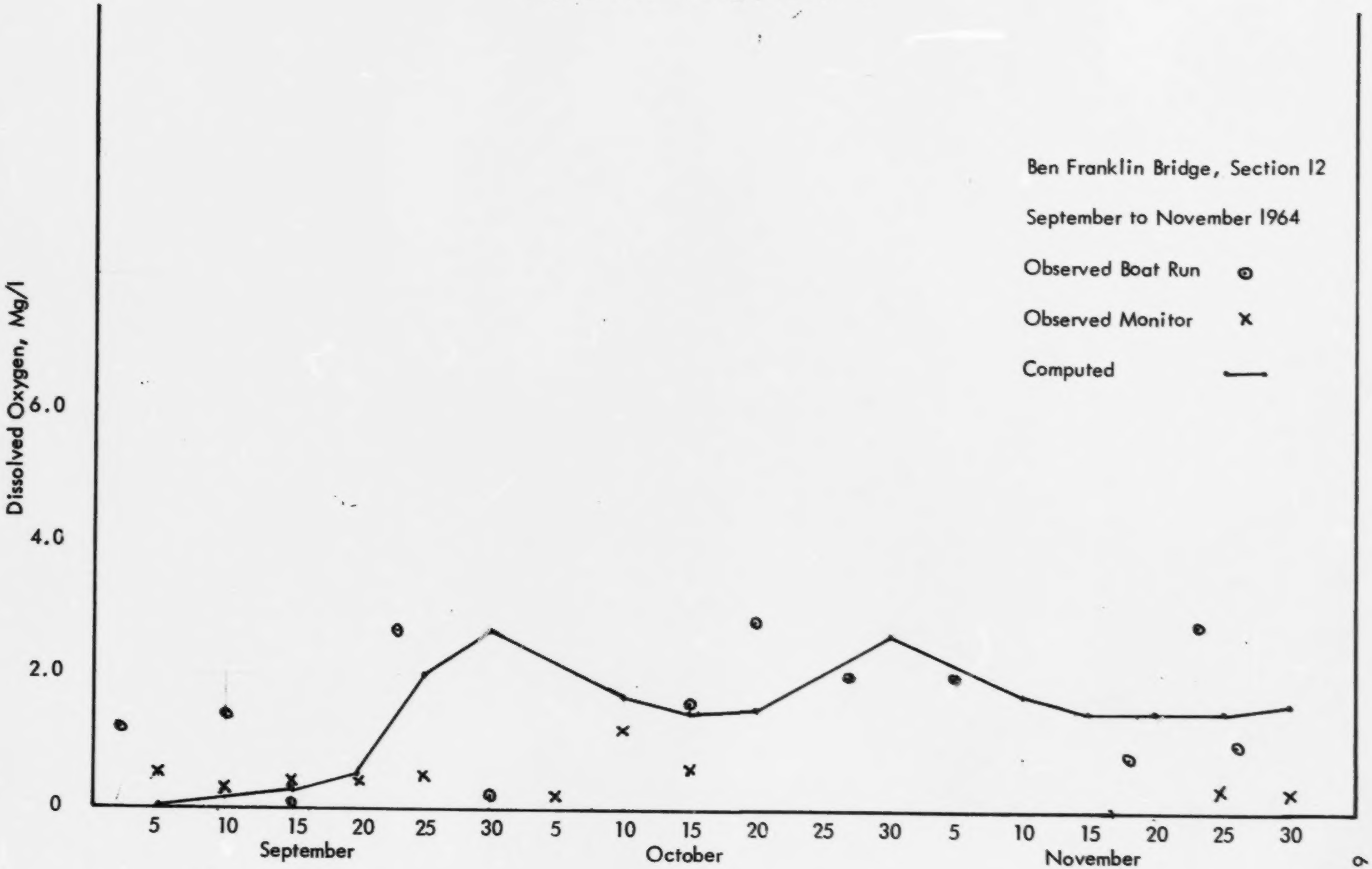


Figure 24c

OBSERVED VS. COMPUTED CHLORIDES, JULY 10, 1964

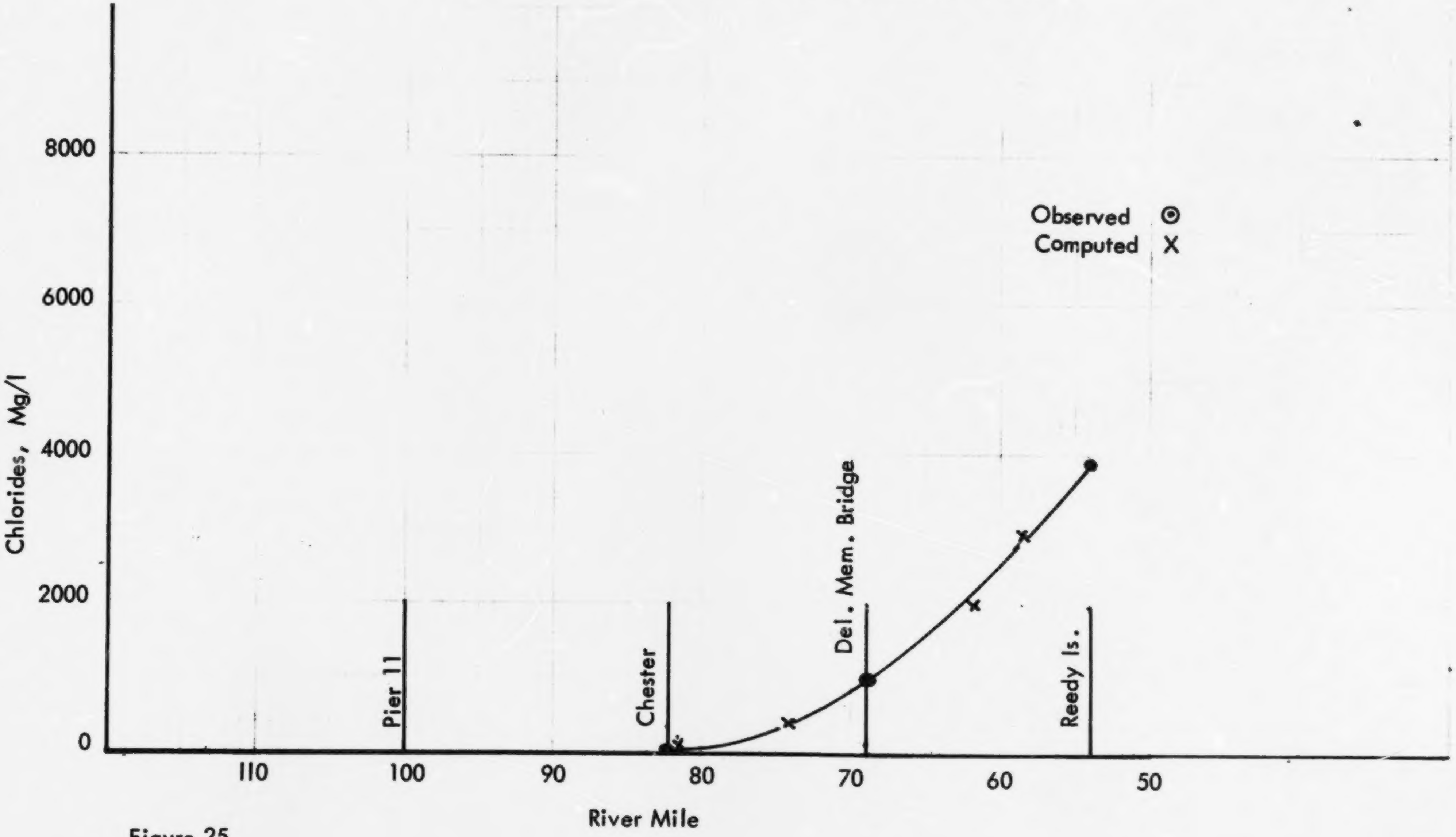


Figure 25

OBSERVED VS. COMPUTED CHLORIDES, OCTOBER 20, 1964

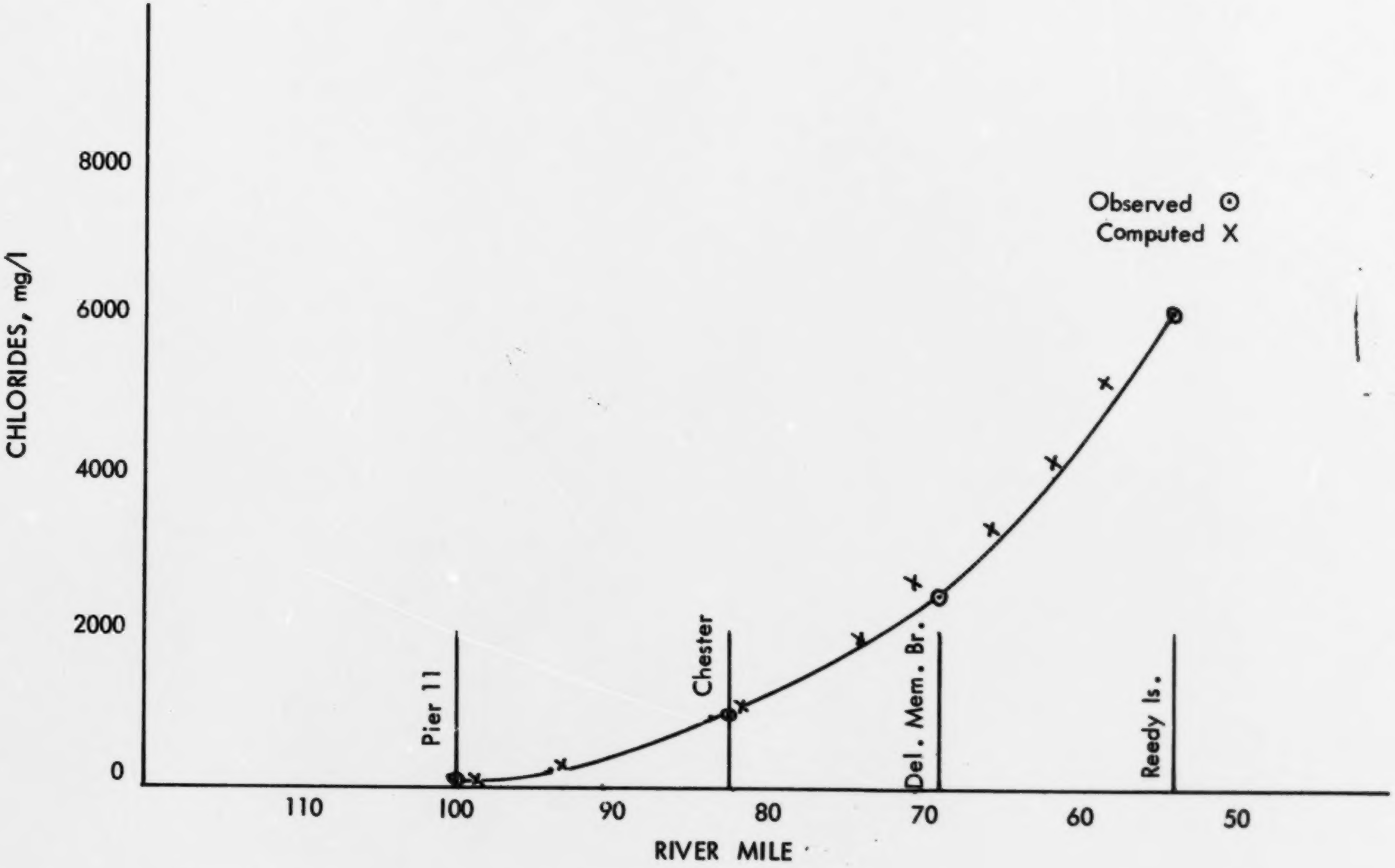


Figure 26

E. Data Storage and Processing. The data that was collected and analyzed by the Delaware Water and Air Resources Commission is being entered into computer storage for retrieval and processing by the STORET system of the Federal Water Quality Administration. Stations were identified by a particular numbering system and the location information includes the river mileage and the latitude and longitude. The river mileage was measured in statue miles from the mouth of the Delaware Bay, measured along the center line of the navigation channel to each station. This is consistent with the mileage and river basin designation system used by STORET. The STORET identification numbers for these stations on the Delaware Estuary are shown in Table 8. Table 9, gives the parameters, the STORET abbreviations and the unit of these parameters as they were entered. In addition, for each parameter there is a five digit parameter identification code number with the abbreviated parameter name assigned by STORET. The statistical measurements that can be determined by the STORET computer include the number of samples analyzed, the maximum, minimum, and mean values of the parameter, the standard deviation and the standard error. Along with the water quality analyses, the dates of each sampling including the time of day and tide stage are given.

The collection and storage of information are being continued. Table 10 shows the typical printout from one of the Estuary stations and Figure 27 a plot of a typical analysis. This type of information is available in many various forms dependent on the needs of the user.

Table 8

STORET NUMBERS FOR DELAWARE ESTUARY STATIONS

Station Name	STORET NO.
Fieldsboro, N.J.	332061
Florence, N.J.	332058
Burlington Bristol Bridge	892080
Torresdale, Phila., Pa.	892077
Palmyra, N. J.	332055
Northeast STP, Phila., Pa.	892074
Ben Franklin Bridge	892071
Wharton Street, Phila., Pa.	892068
Navy Yard, Phila., Pa.	892065
Paulsboro, N.J.	332052
Eddystone, Pa.	892062
Marcus Hook, Pa.	332049
Oldman's Point, N.J.	332046
Cherry Island, Del.	091011
New Castle, Del.	091008
Pea Patch Is., Del.	091005
Reedy Island, Del.	091002

TABLE 9 Parameter Designations

Parameter (1)	STORET Abbreviation (2)	Units (3)
Tide stage	TIDE STAGE	CODE
Water temperature	WATER TEMP	CENT (°C)
Dissolved oxygen	DO	MG/L(milligrams per liter)
Dissolved oxygen saturation	DO, SATUR	PERCENT
Five-day biochemical oxygen demand	BOD, 5 DAY	MG/L
Oxidation reduction potential	REDOX, ORP	MV(millivolts)
Chloride	CHLORIDE, CL	MG/L
Conductivity	CNDUCTVY AT 25C	MICROMHO (see Note 1)
Kjeldahl nitrogen	TOT KJEL N	MG/L(see Note 2)
Ammonia nitrogen	AMMONIA, NH3-N	MG/L " "
Nitrite nitrogen	NITRITE, NO2-N	MG/L " "
Nitrate nitrogen	NITRATE, NO3-N	MG/L " "
Total phosphates	T PO4, PO4	MG/L(see Note 3)
Chlorophyl A	CHLRPHYL A	MG/CU M(see Note 4)
Total coliform	COLIFORM, DLY ENDO	MF/100ML
Fecal coliform	FEC COLI,MF-C44.5	MF/100ML
Fecal streptococcus	STPCOCCI, M-ENTCCS	MF/100ML
pH	PH	SU(standard units)
Total acidity	T AC DITY,CACO3	MG/L(see Note 5)
Total alkalinity	T ALK, CACO3	MG/L " "
Total hardness	TOT HARD, CACO3	MG/L " "
Iron	IRON, TOTAL	UG/L(micrograms per liter)
Zinc	ZINC, ZN	UG/L
Total chromium	CHROMIUM,CR, TOTAL	UG/L
Copper	COPPER, CU	UG/L
Nickel	NICKEL, NI	UG/L
Total solids	RESIDUE, TOTAL	MG/L
Total volatile solids	RESIDUE, TOTAL VOL	MG/L
Total suspended solids	RESIDUE,TOT NFLT	MG/L
Volatile suspended solids	RESIDUE,VOL NFLT	MG/L
Turbidity	TURB, HLGE	PPMSIO2(see Note 6)
Syndets	MBAS	MG/L
Phenols	PHENOLS	UG/L
Threshold odor	ODOR, THRESH	NUMBER

Notes: 1 - micromhos per centimeter at 25°C
2 - milligrams per liter as nitrogen
3 - milligrams per liter as PO4
4 - milligrams per cubic meter
5 - milligrams per liter as CaCO3
6 - parts per million silicon dioxide (units)

TABLE 10

Tabulated Analyses From STORET

DELAWARE RIVER AT BENJAMIN FRANKLIN BRIDGE, PHILADELPHIA, PA.
RIVER MILE 100.15 [illegible] NO 5C
LATITUDE 39°57'10"N STORET NO. 892071
LONGITUDE 75°08'10"W DRBC NO. 42071

DATE	TIME OF DAY	00067 TIDE STAGE CODE	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00310 BOD 5 DAY MG/L	00090 REDOX ORP MV	00940 CHLORIDE CL MG/L	00095 CNDUCTVY AT 25C MICROMHO	00625 TOT KJEL N MG/L	00610 AMMONIA NH3-N MG/L	00615 NITRITE NO2-N MG/L	00620 NITRATE NO3-N MG/L	00650 T PO4 PO4 MG/L	32230 CHLRPHYL A MG/CU M	31503 COLIFORM DLY ENDO MF/100ML	31616 FEC COLI MF-C44.5 MF/100ML	31679 STPCOCCI M-ENTCCS MF/100ML
67/07/06	0922	3	25.0	2.4	29	1.4		14		1.3	0.6	0.070	0.94	1.10		16000	13200	150
67/07/12	1350	3	25.5	1.4	17	3.2		14		1.0	0.6	0.100	0.90	1.30		18000	9000	290
67/07/26	1215	3	27.0	2.5	31	3.8		15		1.2	0.5	0.130	0.40	0.72		9300	2700	70
67/08/01	1115	1	27.5	1.1	14	5.7		21		2.0	0.7	0.200	0.44	0.85		21000	52000	70
67/08/07	1025	3	24.5	3.6	43	4.2		12		0.1	0.1	0.080	0.55	1.40		17000	10000	290
67/08/15	1100	1	27.0	1.7	21	2.9		15		1.4	0.8	0.060	0.45	1.80		51000	40000	790
67/08/21	1030	3	28.0	1.7	22	2.0K		23		2.1	1.4	0.090		1.70		27000	6100	190
67/08/23																		
67/08/28																		
67/09/06	1115	3	24.5	3.6	43	2.5		16		0.7	0.3	0.090		1.30		20000	4900	
67/09/13	1140	1	24.0	1.8	21	2.7		23		2.8	1.3	0.180		1.30	75.0	57000	23000	13
67/09/19	1030	3	26.0	1.8	22	1.9		18		1.6	0.8	0.080		2.00	52.0	110000	36000	720
67/09/27	0845	1	20.0	0.6	7	3.0		23		2.3	1.5	0.170		0.94	75.0	49000	25000	290
67/10/05	1015	3	24.0	1.4	16	1.9		19	295	1.4	0.8	0.140		1.30	40.0	26000	6500	120
67/10/12	1105	1	20.0	0.6	7	4.6		25	340	2.4	1.6	0.410		1.90	26.0	510000	96000	1840
67/10/19	0930	3	18.0	1.6	17	2.1		21	320	1.4	1.0	0.180		1.76	20.0	55000	10700	430
67/10/26	0905	3	16.0	1.6	16	2.8	110	23	335	2.2	1.4	0.190		2.78	26.0	490000	17000	3800
67/11/03	0932	3	14.5	3.4	33	2.2	65	9	315	2.1	1.4	0.070		1.75	16.0	90000	11600	532
67/11/07	1230	3	12.0	7.5	69	3.4	50	11	190	0.7	0.3	0.560		2.25	10.0	120000	9000	880
67/11/16	0810	3	7.0	9.7	80	4.8	70	13	190	1.7	1.0	0.030	0.30	1.75	6.0	90000	22000	1730
67/11/20	1005	3	7.0	10.0	82	2.1	10	12	200	1.2	0.6	0.030	0.30	1.85	9.0	20000	9100	1270
67/11/27	1015	1	7.0	5.5	45	2.9	120	16		2.6	1.6	0.040	0.40	1.85	7.0	12600	1500	150
67/12/04	1040	3	4.0	10.6	81	3.0	40	15	200	1.8	1.0	0.030	0.60	1.20	12.0	25000	2700	2150
67/12/13	1145	1	5.0	10.0	78	3.7	150	14	240	1.4	0.7	0.020	0.30	1.75	21.0	79000	8600	2600
67/12/18	0900	3	4.0	10.0	76	1.8	60	14	165	1.4	0.4	0.020	0.20	1.30	4.0	21000	6000	1300
67/12/27	1035	1	5.0	8.8	69	4.1	180	17	180	1.2	0.6	0.020	0.10	1.20	3.0	30000	9600	1200

TIDE STAGE CODE
1 SAMPLE TAKEN AT HIGH WATER SLACK
3 SAMPLE TAKEN AT LOW WATER SLACK

REMARKS INFORMATION
K ACTUAL VALUE IS KNOWN TO BE LESS THAN VALUE GIVEN
L ACTUAL VALUE IS KNOWN TO BE GREATER THAN VALUE GIVEN

Typical Computor Plot from STORET

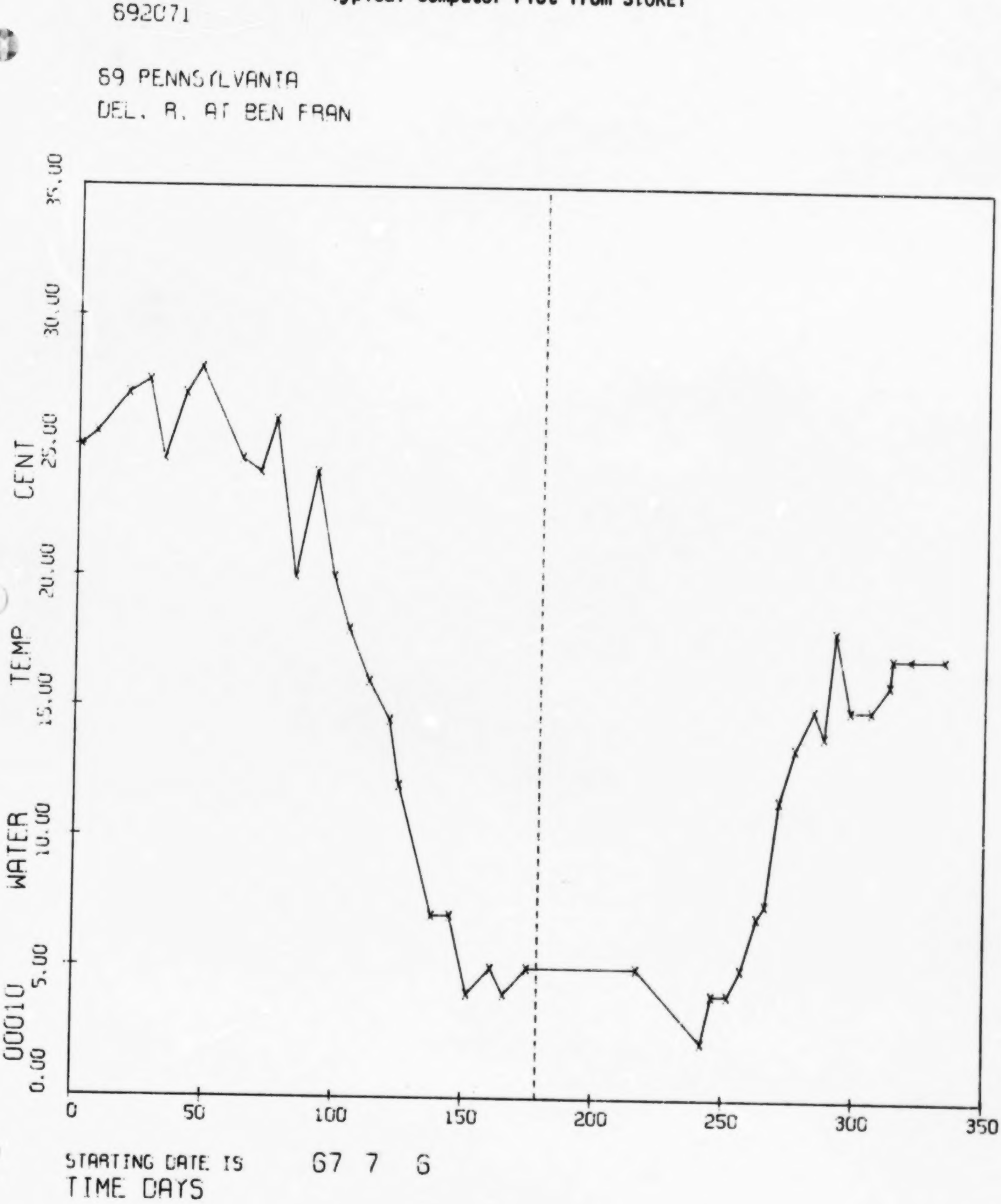


Figure 27

V. Summary and Conclusions

As a result of this demonstration grant for water quality sampling and mathematical modeling, a large-scale sampling program was undertaken in July 1967 in which contracts were let to establish sampling and analyses of important water quality parameters in the Delaware Estuary. This sampling program is continuing beyond the termination of the demonstration grant, now financially supported by the Delaware River Basin Commission.

As part of the established water quality management program, the collected data of various water quality parameters are being used to continue the establishment of the base line for Estuary water quality so that future improvements of water quality as a result of the Estuary Abatement Program for reducing discharge of carbonaceous waste to the Estuary will be demonstratable. In conjunction with the collection of Estuary data, other contracts were established independent of the demonstration grant to sample and analyze discharge effluents and tributary streams to the Estuary.

The comparison of collected data to the water quality standards as outlined in the Basin Regulations - Water Quality show that the dissolved oxygen in the Estuary during the critical summer periods in 1967 and 1968 was much below the required minimum daily average in almost all of the Estuary. This below standard condition is expected to be alleviated once the abatement program is completed in which the by reducing carbonaceous raw waste of industry and municipalities is reduced to meet their allocations. The requirements for fish passage during the spring and fall seasons are also expected to be met. The required 6.5 mg/l of dissolved oxygen for fish passage on a seasonal basis is not being met now in most of the Estuary at the present time. Based on the sampling data, the concentrations of hardness, turbidity, chlorides, and nitrates are within the standards.

When comparing the Estuary data of 1967-69 with that compiled from 1949-63, the median pH ~~appears to have~~ increased during 1967-69; however, this ~~apparent~~ increase is not very large and may not be statistically significant. As expected, high Estuary flows resulted in lower specific conductance levels. The water temperatures in the Estuary for the two study periods were very similar. On the basis of the data shown, the average temperatures were slightly lower for the 1967 period during the summer season than during the 1949-63 period. The comparison of dissolved oxygen profiles during the summer period of 1968 as compared to the average profile of the 1949-63 study, showed that the critical sag in Zone 4 was about the same, reaching 1.5 mg/l dissolved oxygen. At the end of Zone 2 and beginning of Zone 3, the earlier period had a higher dissolved oxygen concentration than that of the steady-state curve of 1968.

The 1964 model was recalibrated and successfully used to reverify the observed steady-state dissolved oxygen profile for 1967 and 1968. The 1967 reverification was shown in the July 1967 Interim Progress Report (10). Estimates of the discharge loads calculated from the sampling of industrial and municipal discharges were used in this reverification. As a result of the computer runs with the steady-state model, it is seen that the modeling technique that DECS established has been substantiated and the calibration to the observed 1964 profile improved.

The time-varying model was calibrated so that dissolved oxygen predictions could be made during the year. This model was also calibrated for chlorides and it appears that the predictive capability of the model for this parameter is quite good. With additional sampling information further down the Estuary, the time-varying model is expected to be successfully extended down to Ship John Light (R. M. 36.9) for predicting chlorides.

On the basis of the work that has been done under this demonstration grant, it is concluded that the study has been worthwhile, so much so that it is being continued on an independent basis by the Delaware River Basin Commission. The water management program now being established demands river data of adequate reliability so that a coordinated abatement program among the states can be continued to be developed. The demonstration grant has provided the necessary initial impetus.

The program of continuing surveillance by these boat runs and by the updating of the mathematical model for predictive purposes of dissolved oxygen, chlorides, and other parameters, conservative and non-conservative, is continuing under the support of the Delaware River Basin Commission. When expected improvement occurs in the Estuary from the abatement program and automatic monitoring systems take over the job of surveillance, the water quality sampling of the Estuary begun with this demonstration grant will have succeeded in its ultimate purpose.

REFERENCES

1. FWPCA, "Delaware Estuary Comprehensive Study," Preliminary Report and Findings," Department of the Interior. (July 1966)

2. O'Connor, Donald J., "Oxygen Balance of an Estuary," Journal ASCE Proceedings, SA3, pg. 2472. (May 1960)

3. Thomann, Robert V., "Mathematical Model for Dissolved Oxygen," Journal ASCE Proceedings, SA5, pg. 3680. (October 1963)

4. USGS Water Supply Paper 1809-0, "Delaware River Water Quality, Bristol to Marcus Hook, August 1949 to December 1963." (1965)

5. Basin Regulations - Water Quality, Delaware River Basin Commission, Trenton, N. J. (March 1968)

6. Public Health Service Drinking Water Standards. (1962)

7. Sawyer, C. N., "Fertilization of Lakes by Agricultural and Urban Drainage," Journal New England Water Works Association, 61:109-127. (1947)

8. U. S. Geological Survey, Water Resources Data for Pennsylvania, Part I. Surface Water Records, 1968, Department of the Interior.

9. Jeglic, John M., "DECS III, Mathematical Simulation of the Estuarine Behavior," Analysis Memo No. 1032, Re-entry Systems Department, General Electric Company, Philadelphia. (July 1967)

10. Delaware River Basin Commission, "Progress Report, Delaware Estuary and Bay Water Quality Sampling and Mathematical Modelling Project." (July 1968)

VI. Appendices

Delaware Contract
$80,000

D E L A W A R E R I V E R B A S I N C O M M I S S I O N

C O O P E R A T I O N A G R E E M E N T

THIS AGREEMENT entered into as of the 1st day of July Nineteen Hundred and Sixty-Seven, by and between the DELAWARE RIVER BASIN COMMISSION, hereinafter known and referred to as the "Commission", and the WATER AND AIR RESOURCES COMMISSION OF THE STATE OF DELAWARE, hereinafter referred to as the "Contractor".

IT IS MUTUALLY AGREED AS FOLLOWS:

1. General Purpose. The purposes of this agreement are:

(a) To establish the base conditions for water quality management in certain areas of the Delaware River Basin;

(b) To measure progress of water quality improvement under the standards adopted by the Delaware River Basin Commission and the program administered to give effect to those standards;

(c) To supplement and refine the projections of the mathematical model used in the Delaware River Estuary Study; and

(d) To provide data for public information relating to water quality objectives in the Delaware River Basin.

2. Agreement. The parties hereto agree that, subject to the availability of appropriations and in accordance with the policies and regulations of their respective authorities, the Cooperative Work Program annexed hereto will be undertaken.

3. Work Program. The Contractor will perform the services and provide the reports required by the Work Program according to competent professional standards.

4. Privileged Information. The Contractor will collect samples, data, and field information as specified in the attached schedule. Any data or information gathered outside the jurisdiction of the Contractor will not be published without consent of the Commission. All work performed under the Work Program will also be subject to the requirements of confidentiality prescribed by Federal law.

5. Payments. The total amount budgeted for the annexed work program is $80,000. The Commission will make progress payments to the Contractor according to the following schedule: July 1, 1967 - $26,700; October 1, 1967 - $17,767; January 1, 1968 - $17,767; April 1, 1968 - $17,766. It is understood and agreed that, if performance by the Contractor is not up to the anticipated level during the first year of the contract due to delays caused by weather (winds, ice, etc.), equipment malfunctions, and in recruitment of personnel, training, or organizational requirements, the lower level of performance will be reflected in reduced progress payments by mutual agreement and the remaining budgeted amount will be available for reprogramming in subsequent years.

6. Amendments. The policies, conditions and procedures covered by this agreement and the annexed Work Program may be revised or amended by mutual agreement of the parties, and the exchange of an appropriate documents of amendment. The budgeted amount may also be revised for periods not covered by the contract.

7. Termination. This agreement will terminate on June 30, 1968, subject to extension by mutual agreement.

IN WITNESS WHEREOF, the parties hereto have executed this agreement the date first above stated.

ATTEST:

W. Brinton Whitall
W. Brinton Whitall, Secretary

DELAWARE RIVER BASIN COMMISSION

By
James F. Wright, Executive Director

WITNESS:

N. C. Kaink

DELAWARE WATER AND AIR RESOURCES COMMISSION

By John C Bryson
John C. Bryson, Executive Director

DELAWARE ESTUARY AND BAY COOPERATIVE WORK PROGRAM

Pursuant to the provisions of the Delaware River Basin Compact, this cooperative work program is hereby entered into by and between the Delaware River Basin Commission and the Water and Air Resources Commission of the State of Delaware.

A. Delaware Estuary

1. Samples shall be collected at approximately weekly intervals at the following stations forty-nine (49) times yearly, at midchannel at a depth of three (3) feet below water surface at high or low water slack. High water slack runs shall be made at about every third run.

Station	River Mile*
Reedy Island	55.0
Pea Patch Island	60.6
New Castle	67.7
Cherry Island	70.7
Oldmans Point	74.9
Marcus Hook	78.2
Eddystone, Pa.	84.4
Paulsboro, N. J.	87.9
Navy Yard	93.3
Wharton St.	98.6
Benjamin Franklin Bridge	100.2
Allegheny Avenue	104.3
Palmyra	107.1
Torresdale	110.3
Burlington Bristol Bridge	117.8
Florence, N. J.	122.4
Fieldsboro	127.6

2. The following analyses shall be made of each sample:

   a. Physical analyses

      (1) Temperature--water and air
      (2) Turbidity
      (3) Conductivity
      (4) ORP
      (5) Threshold odor (above Frankford Creek only)

---

* River mileages locate points in the Commission's channel and stream mileage system.

b. Mineral analyses

(1) pH
(2) Acidity
(3) Alkalinity
(4) Hardness
(5) Chlorides
(6) Total phosphates

c. Nitrogen analyses

(1) Kjeldahl
(2) Ammonia
(3) Nitrite
(4) Nitrate

d. Oxygen analyses

(1) Dissolved oxygen
(2) 5-Day biochemical oxygen demand at 20°C
(3) Chlorophyll-A

e. Bacteriological analyses (membrane filter method)

(1) Total coliform
(2) Fecal coliform
(3) Fecal streptococci

f. Miscellaneous analyses

(1) Warburg studies--collect 8 stations once every month and turn over to Federal Water Pollution Control Administration to conduct analyses

(2) Solids balance - 6 stations monthly--solids data will be collected initially and correlated with turbidity. If proper correlation is obtained, this test will be curtailed or omitted.

(3) Phenols - analysis on bi-monthly basis

(4) Syndets (Measured as MBAS; above Frankford Creek only) - analysis on bi-monthly basis

(3) Metals analyses

  - (a) Chromium
  - (b) Copper
  - (c) Iron
  - (d) Nickel
  - (e) Zinc

B. Miscellaneous Sampling

1. Shallow water sampling shall be conducted as needed, subject to available personnel and funds.

2. Cross-section studies shall be made as required, subject to availability of personnel and funds.

3. Special sampling may be required on bottom deposits, photosynthesis, stormwater overflows, etc.

4. Analyses shall be made as mutually agreed upon.

C. Data

Data shall be submitted to the Delaware River Basin Commission as soon as available, in no case later than one month after sampling.

D. Effective Date

This Program shall take effect upon its execution by both parties.

DELAWARE RIVER BASIN COMMISSION

Cooperation Agreement Supplement

THIS AGREEMENT entered into as of the 28th day of June 1968, by and between the DELAWARE RIVER BASIN COMMISSION, hereinafter known and referred to as the "Commission", and the WATER AND AIR RESOURCES COMMISSION OF THE STATE OF DELAWARE, hereinafter referred to as the "Contractor", supplementing agreement of July 1, 1967.

IT IS MUTUALLY AGREED AS FOLLOWS:

1. Pursuant to Paragraph 7 of the agreement of July 1, 1967, the Contract is hereby extended through the fiscal year ending June 30, 1969.

2. Paragraph 5 of said Contract is amended to read as follows:

> 5. The total amount budgeted for the work program is $80,000. The Commission will make progress payments to the Contractor according to the following schedule:
>
> | | | |
> |---|---|---|
> | August 1, 1968 | - | $26,700; |
> | November 1, 1968 | - | $17,767; |
> | February 1, 1969 | - | $17,767; and |
> | May 1, 1969 | - | $17,766. |
>
> It is understood and agreed that, if performance by the Contractor is not up to the anticipated level during the contract year due to delays in recruitment of personnel, training or organizational requirements, the lower level of performance will be reflected in reduced progress payments by mutual agreement and the remaining budgeted amount will be available for reprogramming in subsequent years.

3. This agreement shall take effect July 1, 1968.

IN WITNESS WHEREOF, the parties hereto have executed this agreement the date first above stated.

ATTEST:

DELAWARE RIVER BASIN COMMISSION
By
James F. Wright
Executive Director

WITNESS:

WATER AND AIR RESOURCES COMMISSION
By John C Bryson
Executive Director

DELAWARE RIVER BASIN COMMISSION

Cooperation Agreement Supplement

THIS AGREEMENT entered into as of the 1st day of July 1969, by and between the DELAWARE RIVER BASIN COMMISSION, hereinafter known and referred to as the "Commission", and the WATER AND AIR RESOURCES COMMISSION OF THE STATE OF DELAWARE, hereinafter referred to as the "Contractor", supplementing agreement of July 1, 1967.

IT IS MUTUALLY AGREED AS FOLLOWS:

A. Pursuant to Paragraph 7 of the agreement of July 1, 1967, the Contract is hereby extended through the fiscal year ending June 30, 1970.

B. Paragraph 5 of said Contract is amended to read as follows:

5. The total amount budgeted for the work program is $80,000. The Commission will make progress payments to the Contractor according to the following schedule:

August 1, 1969 -	$26,700;
November 1, 1969 -	$17,767;
February 1, 1970 -	$17,767; and
May 1, 1970 -	$17,766.

It is understood and agreed that, if performance by the Contractor is not up to the anticipated level during the contract year due to delays in recruitment of personnel, training or organizational requirements, the lower level of performance will be reflected in reduced progress payments by mutual agreement and the remaining budgeted amount will be available for reprogramming in subsequent years.

C. Schedule of Amendments to Delaware Estuary and Bay Cooperative Work Program. (Delaware Estuary and Miscellaneous Sampling - Boat Runs)

Paragraph "A. Delaware Estuary" is amended by the deletion of the following:

e. (3) fecal streptococci

Paragraph "A. Delaware Estuary, d. Oxygen analyses" is amended by the addition of the following:

(4) carbonaceous (first stage) oxygen demand--collect samples as mutually agreed upon and conduct required analyses (multiple bottle or Warburg).

Paragraph "A. Delaware Estuary, f. Miscellaneous analyses" is amended by deleting "(2) Solids Balance - 6 stations monthly..." etc. and substituting therefor the following:

"(2) Solids balance. Solids data will be collected as mutually agreed upon."

Paragraph "A. Delaware Estuary, f." is further amended by deleting "(4) Syndets..." etc. and substituting therefor the following:

"(4) Syndets (Measured as MBAS; above Frankford Creek only) - analysis semi-annually."

Paragraph "A. Delaware Estuary (3) Metals analyses" is amended by the addition of the following:

(f) arsenic
(g) lead
(h) mercury - occasionally

D. This agreement shall take effect July 1, 1969.

IN WITNESS WHEREOF, the parties hereto have executed this agreement the date first above stated.

ATTEST:

DELAWARE RIVER BASIN COMMISSION

By
James F. Wright
Executive Director

WITNESS:

By John C. Bryson
Executive Director
Water and Air Resources Commission

Delaware Contract
$20,000

DELAWARE RIVER BASIN COMMISSION

COOPERATION AGREEMENT

THIS AGREEMENT entered into as of the 1st day of July Nineteen Hundred and Sixty-Seven, by and between the DELAWARE RIVER BASIN COMMISSION, hereinafter known and referred to as the "Commission", and the WATER AND AIR RESOURCES COMMISSION OF THE STATE OF DELAWARE, hereinafter referred to as the "Contractor".

IT IS MUTUALLY AGREED AS FOLLOWS:

1. General Purpose. The purposes of this agreement are:

(a) To establish the base conditions for water quality management in certain areas of the Delaware River Basin;

(b) To measure progress of water quality improvement under the standards adopted by the Delaware River Basin Commission and the program administered to give effect to those standards;

(c) To supplement and refine the projections of the mathematical model used in the Delaware River Estuary Study; and

(d) To provide data for public information relating to water quality objectives in the Delaware River Basin.

2. Agreement. The parties hereto agree that, subject to the availability of appropriations and in accordance with the policies and regulations of their respective authorities, the Cooperative Work Program annexed hereto will be undertaken.

3. Work Program. The Contractor will perform the services and provide the reports required by the Work Program according to competent professional standards.

4. Privileged Information. The Contractor will collect samples, data, and field information as specified in the attached schedule. Any data or information gathered outside the jurisdiction of the Contractor will not be published without consent of the Commission. All work performed under the Work Program will also be subject to the requirements of confidentiality prescribed by Federal law.

5. Payments. The total amount budgeted for the annexed work program is $20,000. The Commission will make progress payments to the Contractor according to the following schedule: August 1, 1967 - $5,000; November 1, 1967 - $5,000; February 1, 1968 - $5,000; and May 1, 1968 - $5,000. It is understood and agreed that, if performance by the Contractor is not up to the anticipated level during the first year of the contract due to delays in recruitment of personnel, training, or organizational requirements, the lower level of performance will be reflected in reduced progress payments by mutual agreement and the remaining budgeted amount will be available for reprogramming in subsequent years.

6. Amendments. The policies, conditions and procedures covered by this agreement and the annexed Work Program may be revised or amended by mutual agreement of the parties, and the exchange of an appropriate documents of amendment. The budgeted amount may also be revised for periods not covered by the contract.

7. Termination. This agreement will terminate on June 30, 1968, subject to extension by mutual agreement.

IN WITNESS WHEREOF, the parties hereto have executed this agreement the date first above stated.

ATTEST:

W. Brinton Whitall

W. Brinton Whitall, Secretary

DELAWARE RIVER BASIN COMMISSION

By

James F. Wright, Executive Director

WITNESS:

N. C. Vasuki

DELAWARE WATER AND AIR RESOURCES
COMMISSION

By John C. Bryson

John C. Bryson, Executive Director

DELAWARE ESTUARY AND BAY COOPERATIVE WORK PROGRAM

Pursuant to the provisions of the Delaware River Basin Compact, this cooperative work program is hereby entered into by and between the Delaware River Basin Commission and the Water and Air Resources Commission of the State of Delaware.

A. Streams

1. The following streams shall be sampled on a monthly basis, at the locations noted. Samples shall be collected at representative points and depths above tide.

Stream	Location	River Mile*
Christina River	3rd Street Bridge, Wilmington	2.3
Brandywine Creek	Wilmington Water Plant	1.9
C & D Canal	Summit Bridge	9.3

2. The St. Jones River shall be sampled at Lebanon Bridge near air base on an occasional basis.

3. Other streams in Delaware tributary to the Delaware Estuary or Bay shall be sampled as needed.

4. Analyses shall be made as noted under Section "D".

B. Waste Discharges

1. The following waste discharges shall be sampled on a monthly basis:

   Allied Chemical, Claymont, Delaware
   Wilmington Sewage Treatment Works, Wilmington, Delaware
   (occasional samples)
   Atlas Chemical, New Castle, Delaware
   Tidewater Oil, Delaware City, Delaware
   DuPont-Edgemoor
   Other major discharges

2. Occasional sampling and analyses may be required at minor discharges.

3. Analyses shall be made as noted under Section "D".

4. Waste volumes at time of sampling shall be recorded.

5. Samples shall be composited by flow over 24 hours or a working cycle.

---

* River mileages locate points in the Commission's channel and stream mileage system.

C. Miscellaneous Sampling

1. Special sampling may be required on bottom deposits, photosynthesis, stormwater overflows, etc.

2. Analyses shall be made as noted under Section "D".

D. Analyses (Streams, Waste Discharges, and Miscellaneous Sampling)

1. Physical analyses
    a. Temperature--water and air
    b. Turbidity
    c. Conductivity
    d. ORP
    e. Solids balance
2. Mineral analyses
    a. pH
    b. Acidity
    c. Alkalinity
    d. Chlorides
    e. Total phosphates
3. Nitrogen analyses
    a. Kjeldahl
    b. Ammonia
    c. Nitrite
    d. Nitrate
4. Oxygen analyses
    a. Dissolved oxygen
    b. BOD_5, or COD for specific industrial wastes
5. Bacteriological analyses—total coliform (membrane filter method)
6. Warburg analyses--samples shall be collected and turned over to the Federal Water Pollution Control Administration for analyses.
7. Metals and special analyses as may be necessary.

E. Data

Data shall be submitted to the Delaware River Basin Commission as soon as available, in no case later than one month after sampling.

F. Effective Date

This Program shall take effect upon its execution by both parties.

DELAWARE RIVER BASIN COMMISSION

Cooperation Agreement Supplement

THIS AGREEMENT entered into as of the 28th day of June 1968, by and between the DELAWARE RIVER BASIN COMMISSION, hereinafter known and referred to as "the Commission", and the WATER AND AIR RESOURCES COMMISSION OF THE STATE OF DELAWARE, hereinafter referred to as the "Contractor", supplementing agreement of July 1, 1967.

IT IS MUTUALLY AGREED AS FOLLOWS:

1. Pursuant to Paragraph 7 of the agreement of July 1, 1967, the Contract is hereby extended through the fiscal year ending June 30, 1969.

2. Paragraph 5 of said Contract is amended to read as follows:

> 5. The total amount budgeted for the work program is $20,000. The Commission will make progress payments to the Contractor according to the following schedule:
> September 1, 1968 - $5,000;
> November 1, 1968 - $5,000;
> February 1, 1969 - $5,000 ; and
> May 1, 1969 - $5,000.
>
> It is understood and agreed that, if performance by the contractor is not up to the anticipated level during the contract year due to delays in recruitment of personnel, training or organizational requirements, the lower level of performance will be reflected in reduced progress payments by mutual agreement and the remaining budgeted amount will be available for reprogramming in subsequent years.

3. This agreement shall take effect July 1, 1968.

IN WITNESS WHEREOF, the parties hereto have executed this agreement the date first above stated.

ATTEST:

WITNESS:

DELAWARE RIVER BASIN COMMISSION
By
James F. Wright,
Executive Director

WATER AND AIR RESOURCES COMMISSION
By John C Bryson
Executive Director

DELAWARE RIVER BASIN COMMISSION

Cooperation Agreement Supplement

THIS AGREEMENT entered into as of the 1st day of July 1969, by and between the DELAWARE RIVER BASIN COMMISSION, hereinafter known and referred to as the "Commission", and the WATER AND AIR RESOURCES COMMISSION OF THE STATE OF DELAWARE, hereinafter referred to as the "Contractor", supplementing agreement of July 1, 1967.

IT IS MUTUALLY AGREED AS FOLLOWS:

A. Pursuant to Paragraph 7 of the agreement of July 1, 1967, the Contract is hereby extended through the fiscal year ending June 30, 1970.

B. Paragraph 5 of said Contract is amended to read as follows:

> 5. The total amount budgeted for the work program is $20,000. The Commission will make progress payments to the Contractor according to the following schedule:
>
> September 1, 1969 - $5,000;
> November 1, 1969 - $5,000;
> February 1, 1970 - $5,000; and
> May 1, 1970 - $5,000.
>
> It is understood and agreed that, if performance by the contractor is not up to the anticipated level during the contract year due to delays in recruitment of personnel, training or organizational requirements, the lower level of performance will be reflected in reduced progress payments by mutual agreement and the remaining budgeted amount will be available for reprogramming in subsequent years.

C. Schedule of Amendments to Delaware Estuary and Bay Cooperative Work Program. (Streams, Waste Discharges and Miscellaneous Sampling)

> Paragraph "B. Waste Discharges" is amended by the addition of the following [ ]:
>
> [6. Both raw waste and treated effluent shall be sampled where physically possible.]

Paragraph "D. Analyses" is amended by the deletion of section 6 and the addition to section 4. of the following [ ]:

[c. carbonaceous (first stage) oxygen demand as mutually agreed]

Paragraph "D. Analyses" is further amended by the addition to section "7. Metals and special analyses as may be necessary" of the following [ ]:

[a. chromium]
[b. copper]
[c. iron]
[d. nickel]
[e. zinc]
[f. arsenic]
[g. lead]

D. This agreement shall take effect July 1, 1969.

IN WITNESS WHEREOF, the parties hereto have executed this agreement the date first above stated.

ATTEST: Arthur E. Peck

DELAWARE RIVER BASIN COMMISSION

By
James F. Wright
Executive Director

WITNESS:

By John C. Bryson
Executive Director
Water and Air Resources Commission

N.J. Contract
$40,000

DELAWARE RIVER BASIN COMMISSION

COOPERATION AGREEMENT

THIS AGREEMENT entered into as of the 14th day of August Nineteen Hundred and Sixty-Seven, by and between the DELAWARE RIVER BASIN COMMISSION, hereinafter known and referred to as the "Commission", and the DEPARTMENT OF HEALTH OF THE STATE OF NEW JERSEY, hereinafter referred to as the "Contractor".

IT IS MUTUALLY AGREED AS FOLLOWS:

1. General Purpose. The purposes of this agreement are:

(a) To establish the base conditions for water quality management in certain areas of the Delaware River Basin;

(b) To measure progress of water quality improvement under the standards adopted by the Delaware River Basin Commission and the program administered to give effect to those standards;

(c) To supplement and refine the projections of the mathematical model used in the Delaware River Estuary Study; and

(d) To provide data for public information relating to water quality objectives in the Delaware River Basin.

2. Agreement. The parties hereto agree that subject to the availability of appropriations and in accordance with the policies and regulations of their respective authorities, the Delaware Estuary and Bay Cooperative Work Program annexed hereto will be undertaken.

3. Work Program. The contractor will perform the services and provide the reports required by the said Work Program according to competent professional standards. The Basin Commission will plan and organize the said Work Program so as to coordinate with other similar work programs being undertaken by the States of Delaware and Pennsylvania, and the Commission staff, and will be responsible for uniform standards, general supervision, and coordination decisions, after consultation with the contractor.

4. Reports. The contractor will provide periodic reports and analyses under the Work Program in such detail and according to such schedule as indicated in said Work Program, and as shall be mutually agreed upon by the respective contracting officers.

5. Privileged information. The contractor will collect samples, data, and field information as specified in the attached schedule. Any data or information gathered outside the jurisdiction of the contractor will not be published without consent of the Commission. All work performed under the Work Program will also be subject to the requirements for confidentiality prescribed by Federal law.

6. Payments. The total amount budgeted for the annexed work program is $40,000. The Commission will make progress payments to the contractor according to the following schedule: August 15, 1967 - $10,000; November 1, 1967 - $10,000; February 1, 1968 - $10,000 and May 1, 1968 - $10,000. It is understood and agreed that, if performance by the contractor is not up to the anticipated level during the first year of the contract due to delays in recruitment of personnel, training, or organizational requirements, the lower level of performance will be reflected in reduced progress payments by mutual agreement and the remaining budgeted amount will be available for reprogramming in subsequent years.

7. Amendments. The policies, conditions and procedures covered by this agreement and the annexed Work Program may be revised or amended by mutual agreement of the parties, and the exchange of an appropriate documents of amendment. The budgeted amount may also be revised, and increased or decreased, so as to adjust payments to actual costs developed as the result of experience.

8. Termination. This agreement will terminate on June 30, 1968, subject to extension by mutual agreement, or prior to June 30, 1968 by either contracting party by 90-days' notice.

IN WITNESS WHEREOF, the parties hereto have executed this agreement the date first above stated.

ATTEST:

W. Brinton Whitall, Secretary

DELAWARE RIVER BASIN COMMISSION

By James F Wright
James F. Wright, Executive Director

WITNESS:

By Roscoe P Kandle
Roscoe P. Kandle, M. D.
State Commissioner of Health

DELAWARE ESTUARY AND BAY COOPERATIVE WORK PROGRAM

Pursuant to the provisions of the Delaware River Basin Compact, this cooperative work program is hereby entered into by and between the Delaware River Basin Commission and the Department of Health of the State of New Jersey.

A. Streams

1. The following streams shall be sampled on a monthly basis at the streams and locations noted. Samples shall be collected at representative points and depths (generally above tide).

Stream	Location (River Mile*)
Delaware River	134.34
Assunpink Creek	
Crosswicks Creek	
Assiscunk Creek	
Rancocas Creek	
Pennsauken Creek	
Cooper River	
Little Timber Creek	
Big Timber Creek	
Newton Creek	
Woodbury Creek	
Mantua Creek	
Raccoon Creek	
Oldman's Creek	
Salem Canal	

2. Other streams in New Jersey tributary to the Delaware River Estuary or Bay shall be sampled as needed.

3. The following analyses shall be made:

   a. Physical analyses

      (1) Temperature--water and air
      (2) Turbidity
      (3) Conductivity
      (4) Solids balance (Solids data to be collected and correlated with turbidity. If correlation is obtained, solids tests may be curtailed or omitted.)
      (5) Threshold odor (above Pennsauken Creek only)

---

* River mileages locate points in the Commission's channel and stream mileage system.

b. Mineral analyses

(1) pH
(2) Acidity
(3) Alkalinity
(4) Hardness
(5) Total phosphates
(6) Chlorides
(7) Phenolic compounds
(8) Syndets (Measured as MBAS; above Pennsauken Creek only)

c. Nitrogen analyses

(1) Kjeldahl
(2) Ammonia
(3) Nitrite
(4) Nitrate

d. Oxygen analyses

(1) Dissolved oxygen
(2) 5-Day biochemical oxygen demand at 20° C, or
COD on specific industrial wastes
(3) Warburg (or multiple bottle K1 determination)
Stream samples - 5 per month; major discharges - monthly

e. Bacteriological analyses

(1) Total coliform (membrane filter method on main-stem Delaware only)
Total coliform - multiple tube on all other sampling points
(2) Fecal coliform - main-stem Delaware only
(3) Fecal streptococci - main-stem Delaware only

f. Metals (and additional special analyses as may be necessary)

(1) Chromium
(2) Copper
(3) Iron
(4) Nickel
(5) Zinc

B. Waste Discharges

1. The following waste discharges shall be sampled on a monthly basis:

Trenton
Hamilton Township
Burlington
Pennsauken-Merchantville
Camden (main plant)
Gloucester City
Woodbury
Paulsboro
Penns Grove
Pennsville Township
Salem
Colorado Fuel & Iron, Roebling
Georgia-Pacific, Delair
MacAndrews & Forbes, Camden
Ruberoid, Gloucester
New Jersey Zinc, Gloucester
Texaco, Westville
Mobil Oil, Paulsboro
Hercules Powder, Gibbstown
DuPont-Repauno, Gibbstown
Monsanto, Bridgeport
DuPont-Carney's Point, Penns Grove
DuPont-Chambers, Deepwater
Other major discharges

2. Quarterly sampling and analyses may be required at minor discharges.

3. Analyses of waste discharges shall be as indicated in Section A.

4. Waste volumes at time of sampling shall be recorded.

5. Samples shall be composited by flow over 24 hours or a working cycle.

C. Miscellaneous Sampling

Special studies may be required on bottom deposits, photosynthesis, stormwater overflow, etc.

D. Such additional possible work as indicated in Sections (A2), (B1), (B2) and (C) shall be carried out only if commensurate with Department sampling and laboratory capabilities.

E. Data Submission

Data shall be submitted to the Delaware River Basin Commission on a monthly basis as soon as available, in no case later than one month after sampling.

F. Effective Date

This Program shall take effect upon its execution by both parties.

DELAWARE RIVER BASIN COMMISSION

Cooperation Agreement Supplement

THIS AGREEMENT entered into as of the 28th day of June 1968, by and between the DELAWARE RIVER BASIN COMMISSION, hereinafter known and referred to as the "Commission", and the DEPARTMENT OF HEALTH OF THE STATE OF NEW JERSEY, hereinafter referred to as the "Contractor", supplementing agreement of August 14, 1967.

IT IS MUTUALLY AGREED AS FOLLOWS:

1. Pursuant to Paragraph 8 of the agreement of August 14, 1967, the Contract is hereby extended through the fiscal year ending June 30, 1969.

2. Paragraph 6 of said Contract is amended to read as follows:

> 6. The total amount budgeted for the work program is $40,000. The Commission will make progress payments to the Contractor according to the following schedule:
> September 1, 1968 - $10,000;
> November 1, 1968 - $10,000;
> February 1, 1969 - $10,000; and
> May 1, 1969 - $10,000.
>
> It is understood and agreed that, if performance by the Contractor is not up to the anticipated level during the contract year due to delays in recruitment of personnel, training or organizational requirements, the lower level of performance will be reflected in reduced progress payments by mutual agreement and the remaining budgeted amount will be available for reprogramming in subsequent years.

3. This agreement shall take effect July 1, 1968.

IN WITNESS WHEREOF, the parties hereto have executed this agreement the date first above stated.

ATTEST: DELAWARE RIVER BASIN COMMISSION

BY James F Wright
James F. Wright,
Executive Director

WITNESS:

BY ______________________________

DELAWARE RIVER BASIN COMMISSION

Cooperation Agreement Supplement

THIS AGREEMENT entered into as of the 1st day of July 1969, by and between the DELAWARE RIVER BASIN COMMISSION, hereinafter known and referred to as the "Commission", and the DEPARTMENT OF HEALTH OF THE STATE OF NEW JERSEY, hereinafter referred to as the "Contractor", supplementing agreement of July 1, 1967.

IT IS MUTUALLY AGREED AS FOLLOWS:

A. Pursuant to Paragraph 7 of the agreement of July 1, 1967, the Contract is hereby extended through the fiscal year ending June 30, 1970.

B. Paragraph 6 of said Contract is amended to read as follows:

5. The total amount budgeted for the work program is $40,000. The Commission will make progress payments to the Contractor according to the following schedule:

October 1, 1969 -	$10,000
December 1, 1969 -	$10,000
March 1, 1970 -	$10,000
June 1, 1970 -	$10,000

It is understood and agreed that, if performance by the Contractor is not up to the anticipated level during the contract year due to organizational requirements, the lower level of performance will be reflected in reduced progress payments by mutual agreement and the remaining budgeted amount will be available for reprogramming in subsequent years.

C. Schedule of Amendments to Delaware Estuary and Bay Cooperative Work Program.

Paragraph "A. Streams, 3.d. Oxygen analyses" is amended by the addition of the following:

(4) Chlorophyll-A (Delaware River only)

Paragraph "A. Streams, f. Metals" is amended by the addition of the following:

(6) Arsenic

(7) Lead

Paragraph "B. Waste Discharges, 1." is amended by the addition of the following:

Tenneco Plastics Division, Tenneco Chemicals, Inc.
Burlington, N. J.

Harshaw Chemical Company, Gloucester City, N. J.

Paragraph "B. Waste Discharges" is amended by the addition of the following:

(6) Both raw waste and treated effluent shall be sampled and sampling frequency shall be such that at least as many samples specified in the original Cooperative Agreement will be collected.

D. This Agreement shall take effect July 1, 1969.

IN WITNESS WHEREOF, the parties hereto have executed this Agreement the date first above stated.

DELAWARE RIVER BASIN COMMISSION

ATTEST:

W. Brinton Whitall

By
James F. Wright
Executive Director

WITNESS:

Richard J Sullivan

Pennsylvania
Contract
9-45000

DELAWARE RIVER BASIN COMMISSION

COOPERATION AGREEMENT

THIS AGREEMENT entered into as of the 10th day of November, Nineteen Hundred and Sixty-Seven, by and between the DELAWARE RIVER BASIN COMMISSION, hereinafter known and referred to as the "Commission", and the DEPARTMENT OF HEALTH OF THE COMMONWEALTH OF PENNSYLVANIA, hereinafter referred to as the "Contractor".

IT IS MUTUALLY AGREED AS FOLLOWS:

1. General Purpose. The purposes of this agreement are:

(a) To establish the base conditions for water quality management in certain areas of the Delaware River Basin;

(b) To measure progress of water quality improvement under the standards adopted by the Delaware River Basin Commission and the program administered to give effect to those standards;

(c) To supplement and refine the projections of the mathematical model used in the Delaware River Estuary Study; and

(d) To provide data for public information relating to water quality objectives in the Delaware River Basin.

2. Agreement. The parties hereto agree that subject to the availability of appropriations and in accordance with the policies and regulations of their respective authorities, the cooperative Work Program annexed hereto will be undertaken.

3. Work Program. The contractor will perform the services and provide the reports required by the Work Program according to competent professional standards. The Basin Commission will plan and organize the work so as to coordinate with other similar work programs being undertaken by the States of New Jersey and Delaware, and the Commission staff, and will be responsible for uniform standards, general supervision, and coordination decisions, after consultation with the contractor.

4. Reports. The contractor will provide periodic reports and analyses under the Work Program in such detail and according to such schedule as shall be mutually agreed upon by the respective contracting officers.

5. Privileged Information. The contractor will collect samples, data, and field information as specified in the attached schedule. Any data or information gathered outside the jurisdiction of the contractor will not be published without consent of the Commission. All work performed under the Work Program will also be subject to the requirements of confidentiality prescribed by Federal law.

6. Payments. The total amount budgeted for the annexed work program is $45,000. The Commission will make progress payments to the contractor according to the following schedule: October 1, 1967 - $15,000; November 1, 1967 - $10,000; February 1, 1968 - $10,000 and May 1, 1968 - $10,000. It is understood and agreed that, if performance by the contractor is not up to the anticipated level during the first year of the contract due to delays in recruitment of personnel, training, or organizational requirements, the lower level of performance will be reflected in reduced progress payments by mutual agreement and the remaining budgeted amount will be available for reprogramming in subsequent years.

7. Amendments. The policies, conditions and procedures covered by this agreement and the annexed Work Program may be revised or amended by mutual agreement of the parties, and the exchange of an appropriate documents of amendment. The budgeted amount may also be revised, and increased or decreased, so as to adjust payments to actual costs developed as the result of experience.

8. Termination. This agreement will terminate on June 30, 1968, subject to extension by mutual agreement.

IN WITNESS WHEREOF, the parties hereto have executed this agreement the date first above stated.

ATTEST:

W. Brinton Whitall
W. Brinton Whitall, Secretary

DELAWARE RIVER BASIN COMMISSION

By James F. Wright
James F. Wright, Executive Director

WITNESS:

By Thomas W. Georges Jr, MD

DELAWARE ESTUARY COOPERATIVE WORK PROGRAM

Pursuant to the provisions of the Delaware River Basin Compact, this cooperative work program is hereby entered into by and between the Delaware River Basin Commission and the Department of Health of the Commonwealth of Pennsylvania.

A. Streams

1. The following streams shall be sampled on a monthly basis at the streams and locations noted. Samples shall be collected at representative points above tide. (Grab Sample)

Stream	Location (River Mile*)
Neshaminy Creek	
Poquessing Creek	
Pennypack Creek	
Frankford Creek	
Schuylkill River	
1. Fairmount Dam	
2. South Street	
Darby Creek	
Chester Creek	

2. Other streams in Pennsylvania tributary to the Delaware Estuary shall be sampled as needed.

3. The following analyses shall be made:

   a. Physical analyses

      (1) Temperature--water and air
      (2) Turbidity
      (3) Conductivity
      (4) Solids balance - solids data to be collected and correlated with turbidity. If correlation is obtained, solids tests may be curtailed or omitted.
      (5) Threshold odor (above Frankford Creek only)

* River mileages locate points in the Commission's channel and stream mileage system.

b. Mineral analyses

(1) pH
(2) Acidity
(3) Alkalinity
(4) Hardness
(5) Total phosphates
(6) Chlorides
(7) Phenols
(8) Syndets (Measured as MBAS; above Frankford Creek only)

c. Nitrogen analyses

(1) Kjeldahl
(2) Ammonia
(3) Nitrite
(4) Nitrate

d. Oxygen analyses

(1) Dissolved oxygen
(2) 5-Day biochemical oxygen demand at 20°C, or
COD for specific industrial wastes
(3) Warburg (or multiple bottle K_1 determination
Stream samples - bi-monthly; major discharges - monthly

e. Bacteriological analyses - total coliform

f. Metals (and additional special analyses as may be necessary)

(1) Chromium
(2) Copper
(3) Iron
(4) Nickel
(5) Zinc

B. Waste Discharges

1. The following waste discharges shall be sampled on a monthly basis:

Lower Bucks County Joint Municipal Authority
Philadelphia N. E.
Philadelphia S. W.
Philadelphia S. E.
Darby Creek Joint Sewer Authority
Muckinipates Joint Sewer Authority
Tinicum Township

Central Delaware Sewer Authority
Chester
Marcus Hook
U. S. Steel, Falls Township
Atlantic Refining Company, Philadelphia
Gulf Oil Company, Philadelphia
Scott Paper, Chester
Sinclair Refining Company, Trainer
FMC Corporation, Marcus Hook
Sun Oil Company–Sunolin Company, Marcus Hook
Other major discharges

2. Quarterly sampling and analyses may be required at minor discharges.

3. Analyses of waste discharges shall be as indicated in Section A.

4. Waste volumes at time of sampling shall be recorded.

5. Samples shall be composited over 24 hours or a working cycle.

C. Miscellaneous Sampling

Special studies may be required on bottom deposits, photosynthesis, stormwater overflow, etc.

D. Data

Data shall be submitted to the Delaware River Basin Commission on a monthly basis as soon as available, in no case later than one month after sampling.

E. Effective Date

This Program shall take effect upon its execution by both parties.

DELAWARE RIVER BASIN COMMISSION

Cooperation Agreement Supplement

THIS AGREEMENT entered into as of the 28th day of June 1968, by and between the DELAWARE RIVER BASIN COMMISSION, hereinafter known and referred to as the "Commission, and the DEPARTMENT OF HEALTH OF THE COMMONWEALTH OF PENNSYLVANIA, hereinafter referred to as the "Contractor", supplementing agreement of November 10, 1967.

IT IS MUTUALLY AGREED AS FOLLOWS:

1. Pursuant to Paragraph 8 of the agreement of November 10,1967, the Contract is hereby extended through the fiscal year ending June 30, 1969.

2. Paragraph 6 of said Contract is amended to read as follows:

> 6. The total amount budgeted for the work program is $45,000. The Commission will make progress payments to the Contractor according to the following schedule:
> September 1, 1968 - $15,000;
> November 1, 1968 - $10,000;
> February 1, 1969 - $10,000; and
> May 1, 1969 - $10,000.
>
> It is understood and agreed that, if performance by the Contractor is not up to the anticipated level during the contract year due to delays in recruitment of personnel, training or organizational requirements, the lower level of performance will be reflected in reduced progress payments by mutual agreement and the remaining budgeted amount will be available for reprogramming in subsequent years.

3. This agreement shall take effect July 1, 1968.

IN WITNESS WHEREOF, the parties hereto have executed this agreement the date first above stated.

ATTEST:
W. D. C. Whittell

WITNESS:
McDonnell

DELAWARE RIVER BASIN COMMISSION
By
James F. Wright
Executive Director

By

DELAWARE RIVER BASIN COMMISSION

Cooperation Agreement Supplement

THIS AGREEMENT entered into as of the 1st day of July 1969, by and between the DELAWARE RIVER BASIN COMMISSION, hereinafter known and referred to as the "Commission" and the DEPARTMENT OF HEALTH OF THE COMMONWEALTH OF PENNSYLVANIA, hereinafter referred to as the "Contractor", supplementing agreement of July 1, 1967.

IT IS MUTUALLY AGREED AS FOLLOWS:

A. Pursuant to Paragraph 7 of the agreement of July 1, 1967, the Contract is hereby extended through the fiscal year ending June 30, 1970.

B. Paragraph 6 of said Contract is amended to read as follows:

5. The total amount budgeted for the work program is $45,000. The Commission will make progress payments to the Contractor according to the following schedule:

September 1, 1969 -	$15,000
November 1, 1969 -	$10,000
February 1, 1970 -	$10,000
May 1, 1970 -	$10,000

It is understood and agreed that, if performance by the Contractor is not up to the anticipated level during the contract year due to delays in recruitment of personnel, training or organizational requirements, the lower level of performance will be reflected in reduced progress payments by mutual agreement and the remaining budgeted amount will be available for reprogramming in subsequent years.

C. Schedule of Amendments to Delaware Estuary Cooperative Work Program.

Paragraph "A. Streams, 3.a. Physical analyses" is amended by deleting "(4) Solids balance - solids data..." etc. and substituting therefor the following [ ]:

[(4) Solids balance - Solids data will be collected as mutually agreed upon.]

Paragraph "A. Streams, 3.e. Bacteriological analyses" is amended by the addition of the following [ ]:

[fecal coliform]

Paragraph "A. Streams 3.f. Metals" is amended by the addition of the following [ ]:

[(6) arsenic]

[(7) lead]

Paragraph "B. Waste Discharges" is amended by the addition of the following [ ]:

[6. Both raw waste and treated effluent shall be sampled, and sampling frequency will be such that at least as many samples as was agreed to in the original cooperative agreement will be collected.]

D. This agreement shall take effect July 1, 1969.

IN WITNESS WHEREOF, the parties hereto have executed this agreement the date first above stated.

ATTEST:

DELAWARE RIVER BASIN COMMISSION

By
James F. Wright
Executive Director

WITNESS:

Mary Margaret McDonnell

By Thomas W Georges, MD
Thomas W. Georges, Jr., M.D.
Acting Secretary of Health

dup?

1 Accession Number
W70-09526

2 Subject Field & Group
6A

SELECTED WATER RESOURCES ABSTRACTS
INPUT TRANSACTION FORM

5 Organization
Delaware River Basin Commission

6 Title
FINAL PROGRESS REPORT DELAWARE ESTUARY AND BAY WATER QUALITY SAMPLING AND MATHEMATICAL MODELING PROJECT

10 Author(s)

16 Project Designation
FWQA Project 16090 DCL---5/70

21 Note
Available from the Clearinghouse as PB 193 799, $3 in paper copy, 65¢ in microfiche

22 Citation
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23 Descriptors (Starred First)
*Mathematical modesl, *Dissolved oxygen, *Biochemical Oxygen demand, *pollution abatement, *Water quality, Water pollution, Oxygen sag, Organic wastes, Waste water treatment.

25 Identifiers (Starred First)
*Parameters of biochemical oxygen demand, Carbonaceous biochemical oxygen demand, Nitrogenous oxygen demand

27 Abstract

This is a report on a demonstration grant from the Federal Water Pollution Control Administration. The principal contents are comparisons of water quality parameters for the Delaware Estuary with those previously estimated for years ending 1963. Data on water quality were also obtained for a number of major pollution sources. Comparisons show that previous mathematical models for the Delaware Estuary can still be used to verify dissolved oxygen levels. Current levels of dissolved oxygen fail to meet the standards established by the Commission. It is stated that in the future, regulation of carbonaceous raw waste of industry and municipalities will be sufficient to meet these standards, but no basis for this prediction is outlined in the report. This report provides background for further analysis of economically feasible alternatives programs on the Delaware River.
(Whipple-Rutgers)

Abstractor
William Whipple, Jr.

Institution
Rutgers - The State University of New Jersey ~~(Center of Competence)~~

WR:102 (REV. JULY 1969)
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